Exhibit B

NewFields

Expert Report
of
Shahrokh Rouhani, Ph.D., P.E.

In The United States District Court for the Eastern District of Missouri
A.O.A., et al. v. The Doe Run Resources Corporation, et al.
Civil Action No. 4:11-cv-00044-CDP (consolidated) (E.D. Mo)

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1 INTRODUCTION

1 I have been retained by King & Spalding LLP on behalf of its clients The Renco Group, Inc., D.R. Acquisition Corp., Doe Run Cayman Holdings, LLC, Ira L. Rennert, The Doe Run Resources Corporation, Theodore P. Fox, III, Marvin M. Kaiser, Albert Bruce Neil, and Jeffrey L. Zelms (collectively, "Defendants") in connection with *A.O.A., et al. v. Doe Run Resources Corp., et al.*, Civil Action No. 4:11-cv-00044-CDP (consolidated) (E.D. Mo). The case revolves around the environmental impacts from the *Complejo Metalúrgico de La Oroya* (CMLO) smelter and refinery operations managed by Doe Run Peru (DRP) between 1997 and 2009.

2 CMLO is located in the town of La Oroya, approximately 180 km east of Lima, Peru, at an elevation of approximately 3,750 m above mean sea level.[1] *Cerro de Pasco Investment Co.* ("CdP") built and operated the CMLO from 1922 to 1974, when the Peruvian government nationalized and transferred its assets to *Centromin*, a Peruvian government-owned entity. Centromin operated the CMLO from 1974 until October 23, 1997, when it was acquired by DRP as part of a privatization process.[2] DRP operated the CMLO until June 2009.[3] As Mr. Connor explains, the widespread CMLO environmental impacts under CdP's and Centromin's ownership during their combined 75 years of operations are well documented.[4]

3 My primary task was to review and opine on the reliability of claims based on statistical models, calculations, and conclusions presented in reports submitted by Dr. David L. MacIntosh, Mr. David A. Sullivan, Dr. Nicolas P. Cheremisinoff on behalf of Plaintiffs (collectively, "Plaintiffs' experts") related to CMLO smelter and refinery operations during DRP ownership. I also considered the report of Dr. Jill Ryer-Power, another Plaintiffs' expert, who relies on the results produced by Dr. MacIntosh and Mr. Sullivan.

4 First, Dr. MacIntosh presented a report, which was subsequently amended twice. I reviewed the statistical components of his most updated expert report, hereinafter referred to as "MacIntosh (2019)." From a statistical point of view, MacIntosh (2019) consists of three parts: (a) presentation of a hypothesis regarding the principal exposure media affecting blood lead levels (BLLs) among children in the La Oroya community; (b) predictive models used to estimate blood lead levels for Plaintiffs; and (c) an allocation of contribution based on reconstructed blood lead levels. My review of MacIntosh (2019) indicated a number of fundamental flaws in his statistical modeling and computations that render his presented results devoid of any technical credibility and his opinions based on those results invalid and unreliable. My findings are summarized as a number of opinions:

- Opinion 1: Dr. MacIntosh's predictive models are based on a fundamentally unscientific procedure.
- Opinion 2: Dr. MacIntosh's predictive models are not statistically reliable.
- Opinion 3: Dr. MacIntosh presents misleading results in support of his unreliable predictive models.

[1] Bianchi 2014, p. 2
[2] Bianchi 2014, p. 2
[3] MacIntosh 2019, p. 7
[4] Connor 2019.

- Opinion 4: Dr. MacIntosh's allocation computations are based on unreliable and speculative models.

5 Second, Mr. Sullivan presents a report, hereinafter referred to as "Sullivan (2019)," that attempts to evaluate air quality and deposition impacts based on available emissions data during DRP's operation of the CMLO from 1997 to 2009. My review of Sullivan (2019) reflects that his model lacks a proper model performance evaluation as recommended by the United States Environmental Protection Agency (EPA) guidance document cited in his report. Mr. Sullivan's model fails the EPA's base screening level, which renders his presented results devoid of any technical reliability. My findings are summarized as the following opinion:

- Opinion 5: Mr. Sullivan's air model is an unreliable model that according to EPA's cited guidance should be disregarded.

6 Third, Dr. Cheremisinoff presents a report, hereinafter referred to as "Cheremisinoff (2019)," which, among other aspects, discusses air pollution management and estimates fugitive emissions from the CMLO during DRP's operations. I reviewed the statistical components of his report, which included regression analyses as part of his evaluation of DRP's efficiency improvements. The findings from my review of Cheremisinoff (2019) can be summarized as the following opinions:

- Opinion 6: Dr. Cheremisinoff's regressions conducted as part of his evaluation of DRP's efficiency improvements reveal a general misunderstanding of basic statistical concepts.
- Opinion 7: Dr. Cheremisinoff's manipulations of air monitoring data are overtly biased and unreliable.

7 I reserve the right to revise and/or supplement my opinions as additional information is provided or acquired. These opinions may also be supplemented to rebut the opinions expressed by other experts in this litigation. I hold all the opinions expressed in this report to a reasonable degree of scientific certainty.

2 EXPERIENCE/QUALIFICATIONS/TRAINING/EDUCATION

8 I am an environmental scientist and professional engineer, a tenured university professor, and a consultant in environmental statistics, modeling, and data analysis. I hold a Ph.D. in Environmental Sciences (1983) and a *S.M.* in Environmental Engineering (1980), both from Harvard University, as well as a B.S. in Civil Engineering and B.A. in Economics from the University of California, Berkeley (1978). In 1990, I was awarded tenure and promoted to Associate Professorship at the Georgia Institute of Technology. I am the Founder/President of NewFields Companies, LLC (NewFields), which is an international partnership of environmental experts.

9 My environmental research dates back to 1980, when I developed optimal geostatistical procedures for the analysis and monitoring of groundwater systems during my post-graduate studies. I subsequently developed geostatistical algorithms to analyze environmental spatial datasets within the framework of geographical information system (GIS) databases. In the course of my professional career, I have conducted research addressing a variety of environmental analytic issues. I have authored and co-authored numerous research publications, several invited reviews

and book chapters, a compendium on applications of geostatistics in environmental and geotechnical engineering, a series of American Society for Testing and Material (ASTM) standard guides for application of geostatistics in environmental site investigations, and a four volume guidance document series on background data analysis for the United States Department of the Navy (DON).

10 I was the National Science Foundation visiting scientist at *Centre de Géostatistique, École Nationale Supérieure des Mines de Paris*, France. I have been active in several professional societies and have served on the editorial boards of the American Geophysical Union (AGU) *Water Resources Research* and the Association for Environmental Health and Sciences (AEHS) *Environmental Forensic* Journals. I was the chair of the American Society of Civil Engineers (ASCE) National Ground Water Hydrology Committee, as well as the chair of the ASCE Task Committee on Geostatistical Techniques in Geohydrology. I have been the expert member of the ASTM Geostatistics Standardization Committee and was responsible for the production of a series of ASTM standard guides on applications of geostatistics in environmental site investigations. I have assisted the U.S. Navy and the U.S. Army as an expert to review their installation restoration projects.

11 During the past three decades, I have led numerous investigations and conducted research in environmental statistics and geostatistics, deterministic and stochastic modeling of environmental systems at Superfund (CERCLA) and Resource Conservation and Recovery Act (RCRA) sites. My recent technical efforts included assisting the United States National Oceanic and Atmospheric Administration (NOAA) by performing a leading role in sampling design and analysis of the comprehensive environmental data collected as part of the *Deepwater Horizon* Natural Resource Damage Assessment (NRDA).

12 A summary of my experience and education is provided in Section 8. My compensation and past witness information are provided in Sections 6 and 7, respectively.

3 INFORMATION RELIED UPON

13 In addition to my training, experience, and general knowledge of environmental and statistical principles, I have reviewed and analyzed the datasets relied upon by Plaintiffs' experts, and relevant documents provided to me by King & Spalding LLP. Section 5 provides the list of cited references.

4 OPINIONS

14 I reached my opinions after reviewing reports submitted by Plaintiffs' experts, including MacIntosh (2019), Sullivan (2019), and Cheremisinoff (2019). This section contains discussions of my opinions.

4.1 Opinion 1: Dr. MacIntosh's predictive models are based on a fundamentally unscientific procedure.

15 Dr. MacIntosh begins his expert report with a hypothesis, postulating that air is the principal exposure medium that affects blood lead levels (BLLs) in children in zones and neighborhoods in and around La Oroya[5] (hereinafter collectively referred to as "La Oroya"), and that the source of air lead contamination is the CMLO during the years in which DRP owned and operated the facility.[6] Although Dr. MacIntosh attempts to justify his hypothesis based on claims such as the dominance of outdoor dust[7] in La Oroya, his report is devoid of any form of statistical testing of his hypothesis or examination of alternative sources and media.

16 The untested single-medium hypothesis is then used as the basis of Dr. MacIntosh's statistical models that treat air lead concentration as the sole exposure variable affecting the BLLs of local children. Dr. MacIntosh's hypothesis becomes the basis of his allocation model, claiming that in the absence of emissions from the CMLO, BLLs of affected children would reduce exponentially regardless of the presence or magnitude of other sources of historical lead contamination in La Oroya. This includes exposure to lead in soil and dust in the La Oroya area from pre-DRP CMLO operations. In the absence of any rigorous or systematic evaluation, Dr. MacIntosh's hypothesis is presented as an irrefutable concept.

17 Dr. Bowers and Mr. Connor provide information about alternative sources of lead in La Oroya, including adobe homes and historical contamination of soil and dust in the area. Dr. MacIntosh considers only air lead concentrations, while explicitly ignoring all other sources of lead contamination, including historically affected soil and dust in La Oroya. He justifies this decision by claiming data paucity.[8] This is an unsubstantiated claim considering that during the specific period covered by Dr. MacIntosh's predictive models, ample lead data were collected from other

[5] "*Upon analyzing the available information, I* [Dr. MacIntosh] *observed that blood lead levels in children of La Oroya at any point in time were strongly associated with the concentration of lead in the air of the community in which they lived at that time* (MacIntosh 2019, p.3)."

[6] "*I* [Dr. MacIntosh] *also observed that lead concentrations in air were the result of current emissions from CMLO* (MacIntosh 2019, p.3)."

[7] MacIntosh (2019, p. 28) states: "*As described in Section 7.0,* ***outdoor dust-related exposure pathways are understood to contribute primarily to BLL in La Oroya*** *because the outdoor locations at homes and schools are primarily composed of asphalt or concrete surfaces…The distinction between outdoor dust-dominated and soil-dominated exposure is important because airborne lead particles that deposit onto hard surfaces outdoors will be washed away over time by precipitation, while those that settle onto soil are comparatively immobile and therefore can be a source of long-term exposure to lead* [emphasis added]."

[8] MacIntosh (2019, p. 15) states: "*Prior investigators of conditions in La Oroya demonstrated that ISE can be used successfully to model BLL in children for locations and times for which data are available on concentrations of lead in dust and other environmental media. However,* ***only limited data on lead concentrations in environmental media are available*** *for the time periods and locations that correspond to when Plaintiffs were 2 or 5 years old* [emphasis added]."

environmental media in La Oroya. These data and corresponding studies are listed by Dr. MacIntosh in Table 7.1 and Attachment 6 of his expert report.

18 Dr. MacIntosh's report is devoid of any form of testing, examination, or validation of his single-medium hypothesis and predictive models. Although he relies on multi-media biokinetic model results,[9] Dr. MacIntosh neglects to subject his single-medium hypothesis to even the most rudimentary statistical evaluations. In other words, his logical construct does not allow the opportunity to reject/refute his hypothesis and predictive models.

19 The absence of rigorous and systematic evaluations makes Dr. MacIntosh's approach fundamentally unscientific because he presents his single-medium hypothesis and predictive models as if they are <u>irrefutable</u>. Consistent with principles of scientific theory,[10] no theory can be considered as scientific unless it is presented as a refutable concept.

20 Based on my assessment, I conclude that Dr. MacIntosh's single-medium hypothesis and ensuing single-medium predictive models are based on a fundamentally unscientific approach.

4.2 Opinion 2. Dr. Macintosh's predictive models are not statistically reliable.

21 Pursuant to the hypothesis that air is the principal exposure medium affecting children in La Oroya, Dr. MacIntosh states that he developed his BLL predictive model[11] by determining the "*statistical relationship between air lead and blood lead of children in La Oroya and calculated a range of likely blood lead levels for the Plaintiffs in this matter.*"[12] For this purpose, he elects to use a single-medium *slope factor model*. Although he acknowledges that slope factor models can accommodate lead concentrations in air and other environmental exposure media,[13] he quickly reverts to a single-medium slope factor model by stating: "*Unlike the biokinetic approach, slope factor analysis does not require concentrations of lead in multiple environmental media. Instead, **a single medium**, usually air, is often found to be sufficient for explaining measured BLLs* [emphasis added]."[14]

22 I understand that EPA (2007, p. 1) has developed and promotes the use of the <u>multi-media</u> integrated exposure uptake biokinetic (IEUBK) model which is specifically designed for "*the prediction of blood lead concentrations in young children exposed to lead **from several sources and by several routes*** [emphasis added]." The IEUBK model allows input from <u>several different environmental media</u>, not just air emissions, and the User's Guide states that "*soil and dust are often the primary sources of Pb* [lead] *exposure at a site* (EPA 2007, p. 15)." Integral (2005) used an integrated stochastic model (ISE) to predict blood lead levels in children. Their ISE model took into account measured concentrations of lead in <u>soil, dust, water, and diet</u>, and accounted for the

[9] MacIntosh (2019, p. 28) states: "*To calculate BLLs, Integral* [2005 and 2008] *used a biokinetic model that it calibrated to site-specific environmental lead and blood lead data.*" Dr. MacIntosh relies on the results of Integral's multi-media biokinetic models to quantify BLL reductions under hypothetical conditions.
[10] Popper (1963) states: "*A theory which is not refutable by any conceivable event is non-scientific. Irrefutability is not a virtue of a theory (as people often think) but a vice*."
[11] Partially depicted on Figure 9.4 of MacIntosh (2019, p. 23)
[12] MacIntosh 2019, p. 3
[13] "*Slope factor models describe statistical relationships between BLL and lead in air and other environmental exposure media*" (MacIntosh 2019, p. 15).
[14] MacIntosh 2019, p. 16

community, age-dependent ingestion rates, ventilation rates, and time spent outdoors (Integral 2005, p. 44). Dr. MacIntosh, however, uses a single-medium slope factor model, controlled by age group and zone, based on measured concentrations in only one medium, *i.e.*, air.

23 Furthermore, Dr. MacIntosh ignores EPA's warnings and caveats about the use of the slope factor regression models, especially those associated with a single medium, including:

- "*Slope factor models are **highly simplified** representations of empirically based regression models in which the slope parameter represents the change in blood Pb concentration projected to occur in association with a change in Pb intake or uptake* [emphasis added]."[15]
- "*However, regression models are based on (and require) paired predictor-outcome data, and, therefore, the resulting predictions are confined to the domain of observations and are typically **not generalizable** to other populations* [emphasis added]."[16]
- "*Regression models also **frequently exclude** numerous parameters that are known to influence human Pb exposures (e.g., soil and dust ingestion rates) and the relationship between human exposure and tissue Pb levels, parameters which are expected to vary spatially and temporally* [emphasis added]."[17]
- "*Thus, **extrapolation** of regression models to other spatial or temporal contexts can be problematic* [emphasis added]."[18]

24 Despite the above limitations, Dr. MacIntosh "***elected*** *to use the slope factor approach to characterize BLLs of the Plaintiffs* [emphasis added]."[19] He cites three studies to justify his choice of a single-medium slope factor model, including Gulson *et al.* (2017), Von Lindern *et al.* (2003), and Richmond-Bryant *et al.* (2014). These studies actually reflect methodologies and assumptions that are fundamentally different from Dr. MacIntosh's selected method. The first two cited studies compare BLLs to lead in *soil/dust*, not lead in *air*. The third cited study, Richmond-Bryant *et al.* (2014), compares BLL and air lead concentrations, but for cases where BLLs and air lead concentrations are vastly lower than those analyzed by Dr. MacIntosh. Citing of the above three studies ignores the fact that slope factor models are neither generalizable nor appropriate for extrapolation.

25 Ironically, the principal finding of Richmond-Bryant *et al.* (2014) is stated as "[c]*omparing the NHANES regression results with those from the literature shows that slope factor increased with decreasing PbA [air lead concentrations] among children 0–11 years of age*." This conclusion implies that the slope factor is not a constant value, and thus, linear regression of BLLs and air lead concentrations is inappropriate. Dr. MacIntosh ignores this finding and instead relies on his inappropriate linear predictive models.

[15] EPA 2013, p. 3-135
[16] EPA 2013, p. 3-118
[17] EPA 2013, p. 3-118
[18] EPA 2013, p. 3-118
[19] MacIntosh 2019, p.16

26 Despite the central role of his predictive models, Dr. MacIntosh fails to disclose or discuss even the most rudimentary statistical measures for the reliability of his predictive linear regression models.[20] There are a variety of such statistical measures for linear regressions that demonstrate the strength and significance of a model, including:

- ***R-squared*** is a measure of linear correlation between two variables, which in this case are the BLL (referred to as the dependent variable) and air lead concentration (referred to as the explanatory variable). R-squared represents the proportion of BLL variance that is explained by air lead concentration. R-squared can also be considered as a measure of goodness-of-fit of a linear model relative to observed values. R-squared varies between 0 and 1, with 1 indicating a perfect linear correlation where 100% of BLL variance is explained by air lead concentration, and 0 indicating absence of any linear correlation where 0% of BLL variance is explained by air lead concentrations.
- ***Correlation Coefficient or R***, which is the square root of R-squared, is a measure of strength and direction of linear correlation between two variables. R varies between -1 and +1, with -1 indicating a perfect negative correlation between two variables, and +1 indicating a perfect positive correlation between two variables. In cases of no correlation, R becomes zero.
- ***p-value*** is the likelihood of no correlation between the dependent and explanatory variables. Often in environmental statistics, when p-value falls below 5%, the relationship is said to be *statistically significant*, *i.e.*, the observed relationship cannot be attributed to chance.

27 Dr. MacIntosh presents R-squared,[21] R,[22] and p-values[23] for his non-predictive models; however, he fails to produce any of these measures for his predictive models, *e.g.*, those partially depicted in his Figures 9.4 and 9.7.[24] Dr. MacIntosh should have presented and discussed statistical measures within the context of the intended use of each regression model. In this case, Dr. MacIntosh asserts that the intended use of his regression models is to account for "*inter-individual variability…at points in time when measurements do not exist.*"[25] In other words, his objective is not merely to assess the presence of a linear relationship between BLLs and air lead concentrations, but to <u>predict</u> BLLs when such measurements are absent. This implies that the desired models should not only be statistically significant with p-values less than 0.05, but also display strong positive correlations with elevated R-squared values, *e.g.*, greater than 0.5.[26]

28 Given Dr. MacIntosh's predictive objective, R-squared, R, and p-values must be assessed at the predicted individual level for each age group and zone considered in the model. Dr. MacIntosh, however, fails to disclose in his report any of these measures for his predictive model. Dr.

[20] Ironically, Dr. MacIntosh presents a number of introductory, non-predictive regressions in his Figures 9.2 and 9.3. Although these results seem to be peripheral to his predictive BLL model, MacIntosh (2019) includes a number of statistical measures to highlight their reliability.
[21] MacIntosh 2019, p. 21 (Figure 9.3) lists R-squared
[22] MacIntosh 2019, p. 17 (Figure 9.2) lists the non-parametric Spearman's correlation coefficients
[23] MacIntosh 2019, p. 22 (Footnote 38) lists the p-value of the variability of BLL among children in a community and time versus the average BLL in that same place and time.
[24] Dr. MacIntosh's production material contained R code files (statistical and graphics programs) which contain a version of his predictive model (Figure 9.4) displaying the computed low R-squared value of 0.234. However, when generating the final figure, the original version of Figure 9.4 was substituted without including the R-squared value.
[25] MacIntosh 2019, p. 21
[26] There is no specific numerical criteria for an elevated R-squared, however, in my experience as an environmental statistician, an R-squared above 0.5 may be considered as a strong correlation. As listed in Table 1, none of the R-squared values in Dr. MacIntosh's predictive models come close to 0.5.

MacIntosh produced his underlying models and data, and I have run the analyses to compute each of these statistical measures (R-squared, R, and p-values) for his predictive model. As explained in the following paragraphs, each of these measures clearly demonstrates that Dr. MacIntosh's model is highly unreliable and has no predictive value.

29 Table 1 shows the R-squared values for Dr. MacIntosh's predicted BLLs for children across various zones and age groups. For example, in La Oroya Antigua, the R-squared for children ages 5.5 to 6.5 years old is only 0.04. This means that 96% of measured BLL variations are <u>unexplained</u> by air lead concentrations. The unexplained proportions are even higher—reaching nearly 100%—for other zones and age groups. Even accepting Dr. MacIntosh's assumptions and looking at the highest R-squared value (0.22 for 6.5-7.5 year olds in La Oroya Nueva), air lead concentrations fail to explain the vast majority (78%) of the BLL variations. Such results suggest that factors other than air lead concentrations are more strongly affecting BLLs of La Oroya children. Dr. MacIntosh ignores these results and continues to rely on his unreliable single-medium predictive model.

Table 1. R-squared of BLL and air lead concentrations across age groups and zones

Age Group	Casaracra	La Oroya Antigua	La Oroya Nueva	Marcavalle
0 - 1.5 yr		0.17	0.00	0.03
1.5 - 2.5 yrs		0.16	0.00	0.05
2.5 - 3.5 yrs		0.15	0.04	0.05
3.5 - 4.5 yrs		0.21	0.01	0.01
4.5 - 5.5 yrs		0.16	0.04	0.00
5.5 - 6.5 yrs		0.04	0.01	0.06
6.5 - 7.5 yrs	0.10	0.11	0.22	0.02
7.5 - 7.9 yrs		0.02	0.00	0.12

30 The low R-squared values reported in Table 1 point to the poor reliability of Dr. MacIntosh's predictive model. These poor correlations are further highlighted in Figure 2, which compares Dr. MacIntosh's individual predicted BLLs against measured BLLs across various zones and age groups. Results of an accurate model would project along the 45-degree diagonal line in each plot. As reflected in Figure 1, this is not the case with Dr. MacIntosh's predictive model for any age group or zone. The absence of such results is further evidence regarding the unreliability of Dr. MacIntosh's predictive model.

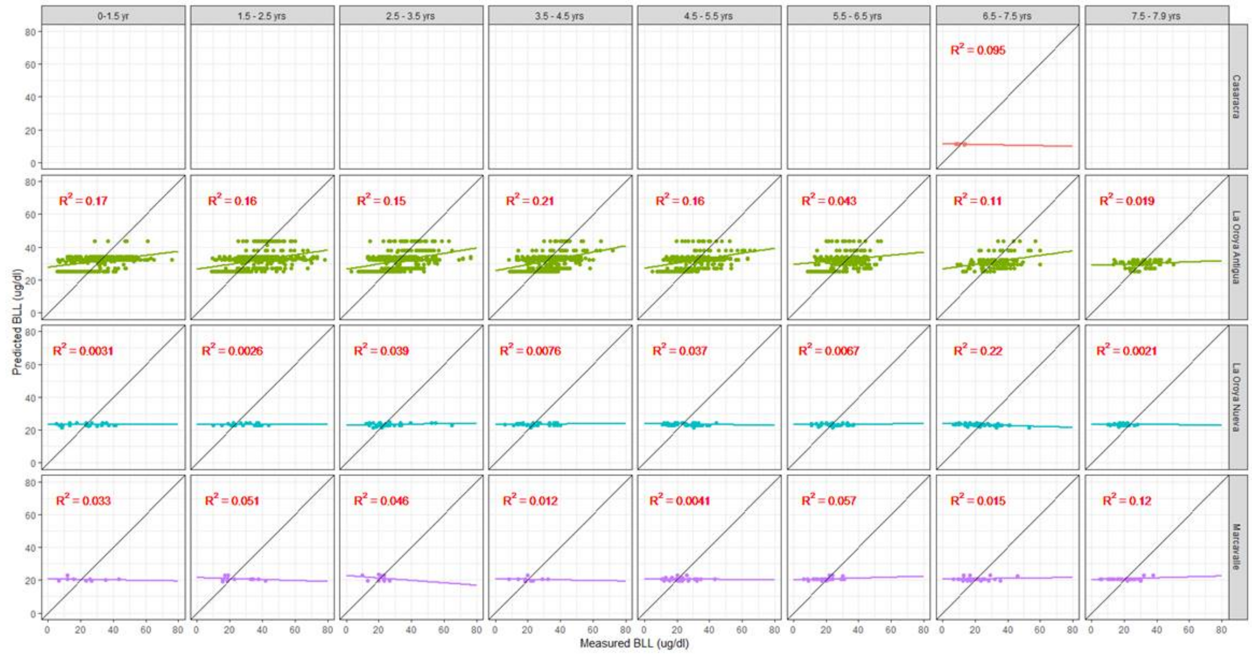


Figure 1. Measured vs. predicted BLLs across all zones and age groups with minimum of 5 observations.

31 As explained above, R values can range from -1 (perfect negative correlation) to 1 (perfect positive correlation). If Dr. MacIntosh's model correctly showed that elevated BLLs were caused by air lead, all the R values would be positive and close to 1. Instead, the above figure demonstrates that for a number of zones and age-groups, Dr. MacIntosh's predictive model yields contrary results, *i.e.*, BLLs decrease as air lead concentrations increase. These contrary results with negative correlation coefficients (R) are presented in red fonts in Table 2. This is further evidence that in many investigated zones air lead concentrations are not the prime factor affecting children's BLLs. Dr. MacIntosh ignores these results, fails to disclose them in his report, and continues to rely on a single-medium predictive model.

Table 2. Correlation coefficients (R) for BLL and air lead concentrations across age groups and zones

Age Group	Casaracra	La Oroya Antigua	La Oroya Nueva	Marcavalle
0 - 1.5 yr		0.41	0.06	-0.18
1.5 - 2.5 yrs		0.40	0.05	-0.22
2.5 - 3.5 yrs		0.39	0.20	-0.22
3.5 - 4.5 yrs		0.46	0.09	-0.11
4.5 - 5.5 yrs		0.39	-0.19	-0.06
5.5 - 6.5 yrs		0.21	0.08	0.24
6.5 - 7.5 yrs	-0.31	0.33	-0.47	0.12
7.5 - 7.9 yrs		0.14	-0.05	0.35

32 Table 3 further assesses the reliability of Dr. MacIntosh's predictive model by listing the computed p-values for BLL and air lead concentrations across age groups and zones. As listed, for many age

groups and zones, the reported linear relationships are not statistically significant, *i.e.*, their p-values are greater than 5%. In these cases the observed model has no significance, and thus, cannot be distinguished from chance. These non-significant results are presented in red font in Table 3.

Table 3. p-values for BLL and air lead concentrations across age groups and zones

Age Group	Casaracra	La Oroya Antigua	La Oroya Nueva	Marcavalle
0 - 1.5 yr		< 0.00001	0.79	0.62
1.5 - 2.5 yrs		< 0.00001	0.83	0.44
2.5 - 3.5 yrs		< 0.00001	0.27	0.58
3.5 - 4.5 yrs		< 0.00001	0.61	0.76
4.5 - 5.5 yrs		< 0.00001	0.18	0.73
5.5 - 6.5 yrs		< 0.00001	0.63	0.13
6.5 - 7.5 yrs	0.50	< 0.00001	0.00	0.45
7.5 - 7.9 yrs		0.24	0.82	0.05

33 The above table also includes linear regressions for a number of age groups in La Oroya Antigua that are statistically significant. These regressions, however, suffer from weak correlations (low R-squared values) and include many contrary results (negative R values), as listed in Tables 1 and 2. In other words, although some of these regressions indicate the presence of statistically significant linear relationships, they are incapable of providing reliable BLL predictions. Dr. MacIntosh's reliance on the single-medium models for predictive purposes is inconsistent with common and generally accepted statistical practices. This is especially alarming when considering EPA's warnings against generalization and extrapolation of single-medium slope-factor models (EPA 2013, p. 3-118). As Dr. Bowers explains, it is particularly inappropriate to try to predict BLLs for individuals as Dr. MacIntosh has done.

34 Dr. MacIntosh's predictive model that is partially displayed in Figure 9.4 of his report uses the 90-day average air lead concentration preceding the date of each child's blood lead test. Dr. MacIntosh attributes his choice of the 90-day averaging period that "*fit the data best*."[27] As explained below, my review of his data indicates that regardless of the averaging period, Dr. MacIntosh's model is a poor fit, and his rationale for using the 90-day averaging period is arbitrary and not truly based on the data.

35 Consider that R-squared is a measure of goodness-of-fit of a linear model relative to the observed values. Dr. MacIntosh's predictive model based on the 90-day averaging period yields a poor fit with an R-squared of 0.234. I used different averaging periods, and calculated their corresponding R-squared values as displayed in Figure 2. This figure indicates that the 90-day averaging period does not produce the best fit. There are other averaging periods that, although still poor fits, would yield R-squared values higher than those produced by Dr. MacIntosh's model. These results cast doubt on the reliability of Dr. MacIntosh's predictive model. The model relied upon by Dr. MacIntosh shows an R-squared of 0.234, indicating that air lead may explain only 23.4% of the BLL variance, with the majority (76.6%) of the variance explained by other sources that Dr. MacIntosh did not consider in his model.

[27] MacIntosh 2019, p. 22, footnote 40

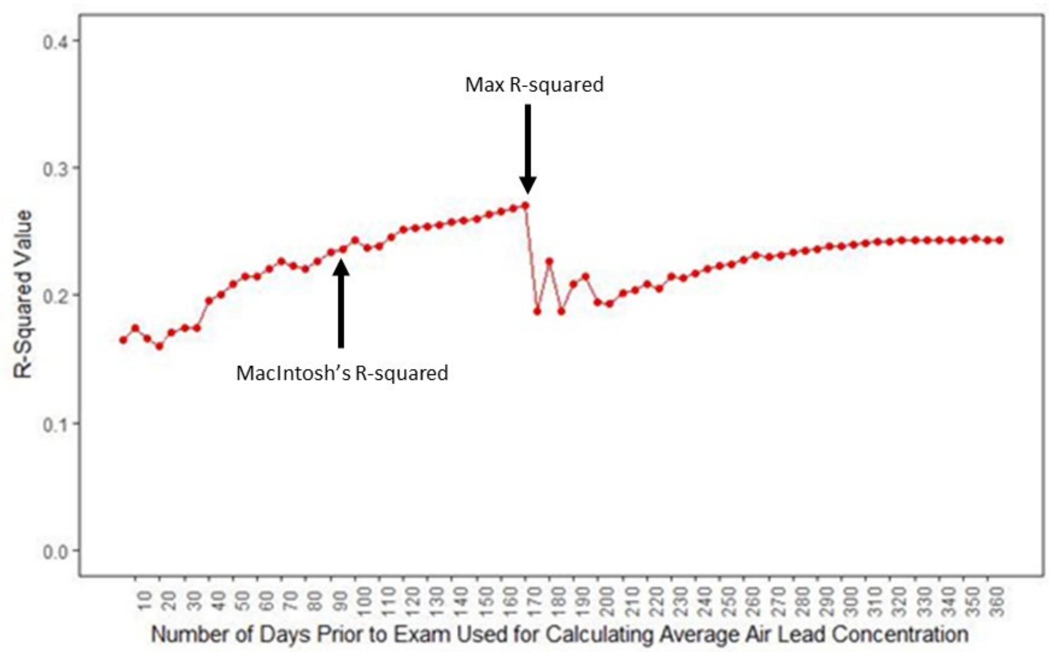


Figure 2. R-squared values of Dr. MacIntosh's predictive model using various periods for calculating the preceding average air lead concentrations.

36 Overall, Dr. MacIntosh's predictive models are severely underfit and are prone to produce contrary and statistically insignificant results. There are substantial variations in measured BLLs within the same day, zone, and age group that Dr. MacIntosh's predictive models do not capture. An underfit model can neither perform well when measured values are available, nor can it be generalized to predict when measured values are missing.[28]

37 Dr. MacIntosh fails to disclose the statistical characteristics of his unreliable predictive models, and instead presents partial and unsubstantiated discussions. Such a failure raises doubt about the scientific integrity of Dr. MacIntosh's reported results. Based on my assessment, I conclude that Dr. MacIntosh's predictive models are inadequate to generalize to individual plaintiffs, and any estimate from this model should be considered unreliable.

[28] Gareth *et al.* 2013, p. 29.

4.3 Opinion 3: Dr. MacIntosh presents misleading results in support of his unreliable predictive models.

38 MacIntosh (2019) includes a number of misleading discussions to convince the reader of the reliability of his predictive model results, including results presented and discussed in his Table 9.3 and Figure 9.6.

4.3.1 Dr. MacIntosh's predicted BLLs of individual Plaintiffs

39 Dr. MacIntosh uses his model to predict the BLLs of 17 individual Plaintiffs. He presents the results along with the upper and lower prediction intervals of his model in Table 9.3 (MacIntosh 2019, pp. 24-25). Dr. MacIntosh compares the measured BLLs in Table 9.3 to his calculated 95% prediction interval to justify the performance of his model. He then asserts that *"These comparisons indicate that this approach yields reliable calculations of BLLs for the Plaintiffs…."*[29] This conclusion is not supported by the data.

40 Dr. MacIntosh misrepresents the occurrence of an observed value within its 95% prediction interval as an indication of model reliability. In regression analysis, the prediction interval describes the uncertainty of a single prediction by providing a range of values and associated probability (95% in this case) for that prediction. Dr. MacIntosh erroneously refers to intervals listed in Table 9.3 and depicted in Figure 9.4 as "confidence intervals" (MacIntosh 2019, p. 23). Confidence intervals are typically associated with estimated values such as the mean, while prediction intervals are associated with the range of variation of individual values. For more information, readers are referred to Gareth *et al.* (2013, p. 66).

41 The size of the 95% prediction interval is a measure of model uncertainty. When the uncertainty of the underlying predictive model increases, the range of the 95% prediction interval will also increase. An unreliable model yields a wide 95% prediction interval. Accordingly, contrary to Dr. MacIntosh's assertion, the occurrence of an observed value within a wide prediction interval is not indicative of a reliable model.

42 Prediction intervals are often used in regression analysis as a measure of model uncertainty. A model and its prediction interval are typically evaluated relative to the intended use. Using the data provided in Dr. MacIntosh's Table 9.3, the average size of the 95% prediction intervals for the 2, 5, and 7-year age groups are 39.3, 39.8, and 40.3 µg/dL, respectively. These intervals are <u>an order-of-magnitude</u> larger than Dr. MacIntosh's assumed background BLL range of 2 to 5 µg/dL.[30] For example, we may consider just one of the Plaintiffs, D'Alessandro Farith Godoy Cuadrado at age 5. Dr. MacIntosh's model can only reliably (95% confidence) predict that this individual's BLL would be measured between 1.44 µg/d and 40.1 µg/dL.[31] Therefore, Dr. MacIntosh's models lack adequate predictive resolution or certainty to differentiate BLLs in children from background.

[29] MacIntosh 2019, p. 23
[30] MacIntosh, 2019 Figure 9.7
[31] MacIntosh, 2019 Table 9.3

43 Dr. MacIntosh's comparison of measured versus predicted BLL pairs, listed in his Table 9.3, indicates that most measured BLLs exceed their corresponding average predicted values. Rather than indicating a conservative model, these results suggest that the selected Plaintiffs with measured and predicted BLLs are not representative of the central tendency of the data used in the construction of Dr. MacIntosh's predictive models. Dr. MacIntosh conceded during his deposition that such underestimations are attributable to "sampling bias" during the selection of Plaintiffs.[32] Nonetheless, he claims in his report that: "*These comparisons indicate that this approach yields reliable calculations of BLLs for the Plaintiffs that may underestimate, but most likely do not overestimate, actual BLLs*."[33] Dr. MacIntosh's presumption that his models are reliable and conservative estimators of BLLs is statistically unfounded and contradictory to his deposition statements regarding biases during the selection of Plaintiffs.

44 The reported uncertainty of Dr. MacIntosh's predictive models shows prediction intervals of ~ 40 µg/dL; these levels are insufficient to reliably predict individual BLLs in the absence of measured data. Therefore, it is my opinion that Dr. MacIntosh's predictive models cannot be used to estimate or predict individual Plaintiffs' BLLs to any reasonable degree of reliability under well-accepted principles of statistics.

45 Furthermore, Dr. Ryer-Powder (2019) relies on Dr. MacIntosh's unreliable single-medium predictive model results, including predicted BLLs for six of the individual Plaintiffs.[34] Reliance on such results casts doubts on the technical reliability of reported claims in Dr. Ryer-Powder's opinions.

4.3.2 Dr. MacIntosh's pseudo-validation

46 Dr. MacIntosh's Figure 9.6 depicts a visual correlation between measured annual average BLLs and measured annual average air lead concentrations. He then uses this visual correlation to justify his predictive single-medium model presented as the blue line in his Figure 9.7. The pseudo-validation process depicted in Figure 9.6 does not actually evaluate the accuracy or reliability of any of his predictive models. Instead, this figure is intended to visually manipulate the reader into believing that BLLs and air lead concentrations always follow similar patterns.

47 When reviewing Dr. MacIntosh's R files,[35] I noticed that he performed similar pseudo-validations for other zones, as displayed in Figures 3 and 4 below, which are generated directly from his own R code. Dr. MacIntosh, however, did not include any of these figures in his report. Unlike Dr. MacIntosh's Figure 9.7, these figures indicate that measured BLLs and air lead concentrations do not follow the same temporal patterns, *i.e.*, the red lines (the average annual BLLs) move opposite to the blue lines (the average annual lead emissions) and the green lines (the average annual air lead concentrations). For these two areas (La Oroya Nueva and Marcavalle), the figures show BLLs rising as lead in air emissions and lead in air go down. Thus, these figures reflect data

[32] MacIntosh Deposition, May 14, 2019, p. 183.
[33] MacIntosh, 2019, p. 23
[34] Ryer-Powder 2019, Table 4, p. 19
[35] R refers to a language for statistical computing and graphics (https://www.r-project.org/about.html). Dr. MacIntosh's production material contained R code files, including BLL 0_7 Analysis (06-07-2019).rmd.

directly contrary to Dr. MacIntosh's single-medium hypothesis. Failure to disclose these results casts doubt on the scientific integrity of claims made and opinions stated in MacIntosh (2019).

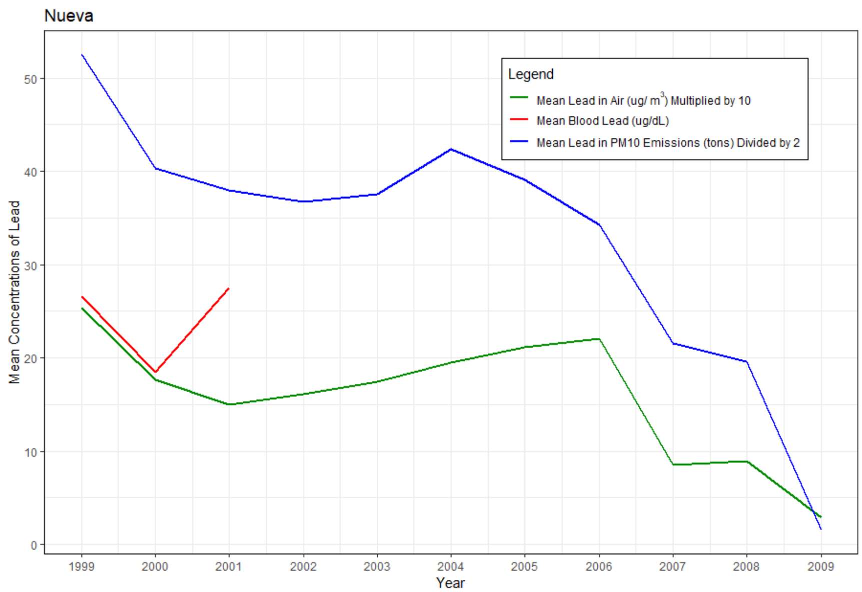


Figure 3. La Oroya Nueva pseudo-validation (excluded from MacIntosh expert report).

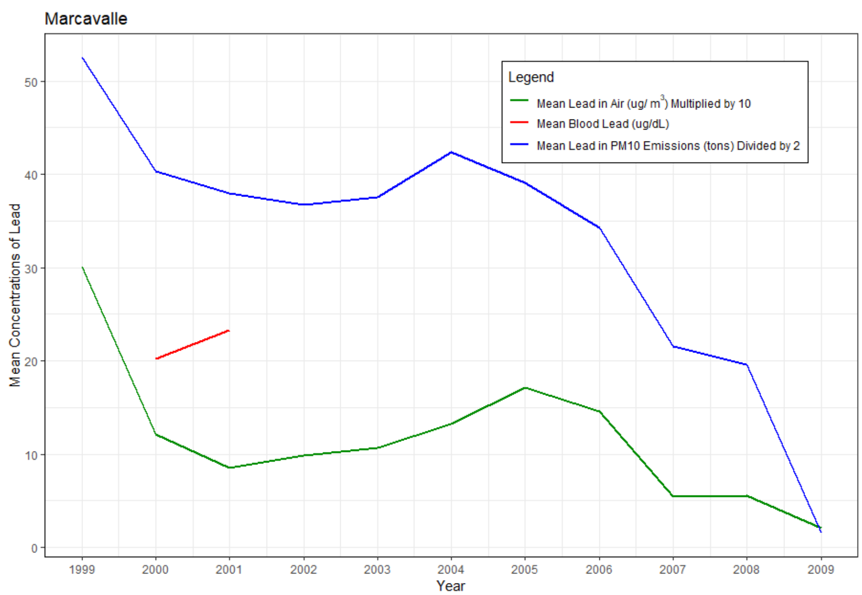


Figure 4. Marcavalle pseudo-validation (excluded from MacIntosh expert report).

4.4 Opinion 4: Dr. MacIntosh's allocation computations are based on unreliable and speculative models.

48 Dr. MacIntosh's Figure 9.7 provides the basis for his BLL allocation that he attributes to DRP's operations. I have reviewed the underlying data and models and identified several errors and inaccuracies in Figure 9.7 that have the effect of artificially increasing DRP's attribution of individual BLLs.

4.4.1 Dr. MacIntosh's "Calculated BLL from Air"

49 In Section 9.2.3, Dr. MacIntosh states that his "*Calculated BLL from Air*" (the blue line model in his Figure 9.7) is calculated "*as described in Section 9.1.3.*" In reality, his blue line model is not representative of the model discussed in Section 9.1.3 (the Section 9.1.3 model). The blue line in Figure 9.7 contains several statistical discrepancies that differentiate it from the Section 9.1.3 model, including:

- Dr. MacIntosh's blue line model differs from the Section 9.1.3 model by lacking the age group control and excluding BLLs of children within the 7-year-old group.
- Although the blue line model parameters are calculated based on the original 90-day average air lead concentrations, in the estimation process, Dr. MacIntosh substitutes the 365-day average air lead concentrations.
- The Section 9.1.3 model is constructed using measured BLL and air lead concentrations between 2000-2001 and 2004-2007. The blue line model, however, is extrapolated across a 15 year time period from 1995 to 2009 with no consideration regarding the unreliability of extrapolated values.
- The values of the blue line model for the years 2010 and 2011 are based on a speculative and untested decay function.

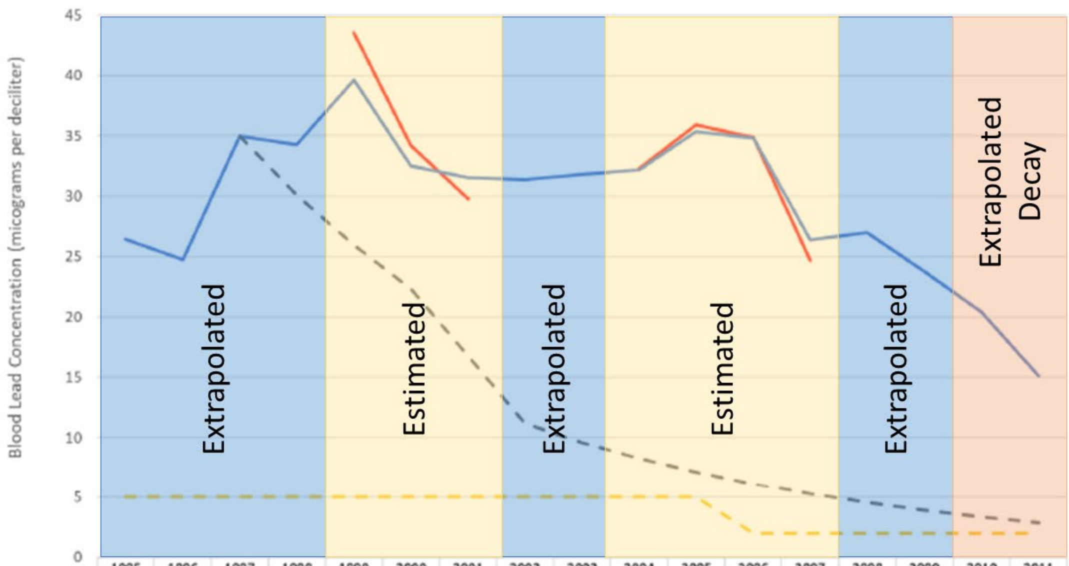
50 When I reviewed the regression equation used in Dr. MacIntosh's blue line model, I noticed that the age group control had been removed, and Dr. MacIntosh had created a separate model with different coefficients. He also excluded 346 measured BLLs for children in the 7-year-old age group. This inconsistency is not addressed or explained anywhere in his report.[36]

51 Another problematic feature of Dr. MacIntosh's blue line model is the choice of the averaging period for air lead concentrations. The coefficients of his blue line model are calculated using the average 90-day air lead concentrations as described in Section 9.1.3. He retains the same coefficients, but substitutes the average 365-day air lead concentrations to generate his blue line from 1995 to 2009. Not only is his documentation of the model incorrect, but his procedure in Figure 9.7 breaks with basic statistical and regression principles which require using the same explanatory variables as the original variables. It is inappropriate under the generally-accepted principles of statistics to build a model using one set of input variables and apply it to a different set of input variables during the estimation.

[36] Dr. MacIntosh concedes during his May 14, 2019 deposition (p. 171) to the age group inconsistency between his Section 9.1.3 model and the blue line model.

52 The last two values of the blue line model for the years 2010 and 2011 are supposedly based on Dr. MacIntosh's speculative and untested decay values. My review indicated that although the 2010 value follows a 55-month half-life decay as suggested in Section 9.2.3 of his report, the 2011 value is based on an equation that corresponds to a much faster decay rate. MacIntosh (2019) is devoid of any information regarding the rationale or reason behind variations among these speculative decay rates.

53 Dr. MacIntosh's Section 9.1.3 model is constructed on a non-continuous period of seven (7) years when measured contemporaneous BLL and air lead concentrations are available. As stated above, after removing the age control and excluding BLLs of 7-year olds, the blue line model is generated and extrapolated over a much longer time period as displayed in Figure 5 below. As discussed in Opinions 2 and 3, Dr. MacIntosh's predictive models perform poorly when compared to available contemporaneous measured BLLs and air lead concentrations. Their performance is expected to be even worse when model results are extrapolated to the years without any measured BLLs. Relying on such unreliable extrapolated values for allocation purposes is technically unacceptable and contrary to EPA recommendations.[37]



	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Measured BLL					43.5	34.2	29.8			32.3	35.9	34.9	24.7				
Calculated BLL from air	26.4	24.8	35.0	34.2	39.6	32.5	31.5	31.4	31.8	32.2	35.4	34.8	26.4	27.0	23.8	20.4	15.1
Pre-Doe Run smelter BLL			35.0	30.1	25.9	22.3	16.7	11.2	9.6	8.3	7.1	6.1	5.3	4.5	3.9	3.4	2.9
Non-smelter BLL	5	5	5	5	5	5	5	5	5	5	5	2	2	2	2	2	2
Doe Run BLL	0.0	0.0	0.0	4.1	17.6	11.9	13.1	20.2	22.2	24.0	28.8	28.8	19.4	22.5	19.8	17.1	12.3
%Total BLL as Doe Run	0%	0%	0%	12%	40%	35%	44%	64%	70%	74%	80%	82%	79%	83%	84%	84%	81%

Year

Figure 5. Reproduction of Figure 9.7 of MacIntosh (2019) with periods of extrapolated values used in the allocation methodology[38]

[37] EPA (2013, p. 3-118): "*Thus, **extrapolation** of regression models to other spatial or temporal contexts can be problematic* [emphasis added]."

[38] My review of Dr. MacIntosh's Excel file ("DRP Attributable (06-07-2019).xlsx") indicates that he uses measured average BLLs in each investigated zone for 1999 to 2001 and 2004-2007 periods for allocation purposes.

54 As such, Dr. MacIntosh's blue line model is fundamentally different from the model "described in Section 9.1.3."[39] It is misleading for Dr. MacIntosh to describe his model in one section and use an entirely different and unexplained model to compute the allocations presented in Figure 9.7.

4.4.2 Dr. MacIntosh's "Pre-Doe Run Smelter BLL"

55 Dr. MacIntosh's decay model is based on a 55-month half-life, which I understand to be, in itself, a highly speculative assumption, as Dr. Bowers explains. Dr. MacIntosh's decay model diverges from the presumed 55-month half-life decay pattern in 2001 and 2002 to supposedly account for DRP's community cleanup program.[40] Dr. MacIntosh fails to justify the imposition of a 50% reduction over a span of only two years purportedly attributable to a community cleanup program in his hypothetical post-smelter decay scenario.

56 The review of Dr. MacIntosh's decay model raises a number of problematic issues:

- DRP's community cleanup program lasted more than two years. Dr. MacIntosh does not provide any justification for compressing the impact of the program into a two-year interval.
- Earlier in the report, Dr. MacIntosh cites similar BLL reductions based on the comparison of historical high BLLs relative to the results of a steady state model (MacIntosh 2019, p.28). A steady state model by definition represents the results after the system attains equilibrium, which may take many years. Furthermore, the cited steady state model results were predicated on substantial concurrent reductions of lead concentration sources in all affected media, including air, soil, dust, water, and diet.[41] Therefore, these steady state results in no way suggest the occurrence of rapid reductions in absence of other corrective measures.
- According to MacIntosh (2019, p. 29-30), DRP's community cleanup campaigns focused on surficial dust and street washing rather than any soil removal. Dr. MacIntosh considers soil contamination as the primary long-term sources of historical contaminations.[42] As explained by Mr. Connor, most of this legacy source would have been unaffected by DRP's cleanup measures. Therefore, Dr. MacIntosh's speculation about a 50% reduction over a two-year period is at best unsubstantiated, if not misleading.

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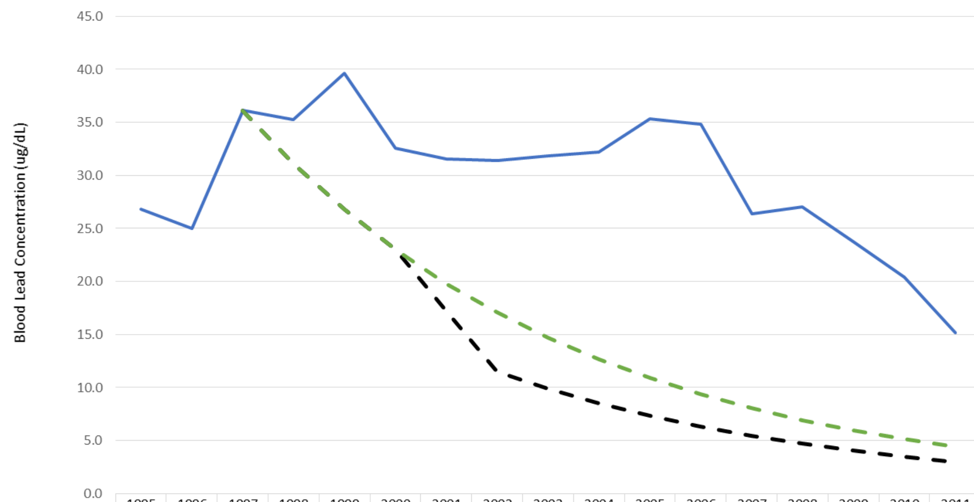
[39] MacIntosh 2019, p. 34.

[40] MacIntosh (2019, p. 34) states: "*To be conservative, I applied the 50% decline in BLLs over two years that occurred in Smelterville, ID to the period 2000 – 2002 although the programs continued in 2003 through at least 2006*."

[41] Integral 2008, Table 6-20.

[42] MacIntosh (2019, p. 29): "*The distinction between **outdoor dust-dominated** and **soil-dominated exposure** is important because airborne lead particles that deposit onto hard surfaces outdoors will be washed away over time by precipitation, while those that settle onto soil are comparatively immobile and therefore can be a source of long-term exposure to lead* [emphasis added]."

- Under Dr. MacIntosh's allocation methodology, DRP's community cleanup triggers an immediate increase in its BLL allocation. These counterintuitive results penalize DRP by assuming that its actions affected all of the historical sources. Such an assumption is clearly unsubstantiated as the program had no component for removal of contaminated soil (MacIntosh 2019, p. 29-30). Ironically, under Dr. MacIntosh's allocation methodology, if DRP had not implemented the cleanup program, its share of BLL allocation would be substantially lower, as displayed in Figure 6.



	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
MacIntosh Calculated BLL from air (365-day avg.)	26.8	25.0	36.1	35.3	39.6	32.5	31.5	31.4	31.8	32.2	35.4	34.8	26.4	27.0	23.8	20.4	15.1
55-month Half-Life (Cleanup)			36.1	31.1	26.8	23.0	17.3	11.5	9.9	8.5	7.3	6.3	5.4	4.7	4.0	3.5	3.0
DRPE % BLL (Cleanup)	0%	0%	0%	12%	38%	33%	42%	63%	69%	74%	80%	82%	78%	83%	83%	83%	80%
55-month BLL Half-Life (No cleanup)			36.1	31.1	26.8	23.0	19.8	17.1	14.7	12.6	10.9	9.4	8.1	6.9	6.0	5.1	4.4
DRPE % BLL (No Cleanup)	0%	0%	0%	12%	38%	33%	33%	46%	54%	61%	70%	73%	67%	74%	75%	75%	71%

Figure 6. MacIntosh's cleanup (black dashed) and no-cleanup (green dashed) decay scenarios and their effects on DRP BLL allocations

- Dr. MacIntosh's hypothetical decay model approaches an asymptotic value of zero. Typically, a decay model should asymptotically approach background levels, and not zero. According to Dr. MacIntosh's decay model, displayed in his Figure 9.7, BLLs would have fallen below Dr. MacIntosh's background levels by 2014 (displayed as the dashed yellow line in Figure 7). As others have indicated, the general background BLL in Peru is approximately 8 µg/dL.[43] Under this condition, Dr. MacIntosh's hypothetical decay model would have fallen below background by 2005 (Figure 7). Dr. MacIntosh does not provide any support or justification for such counterintuitive outcomes.

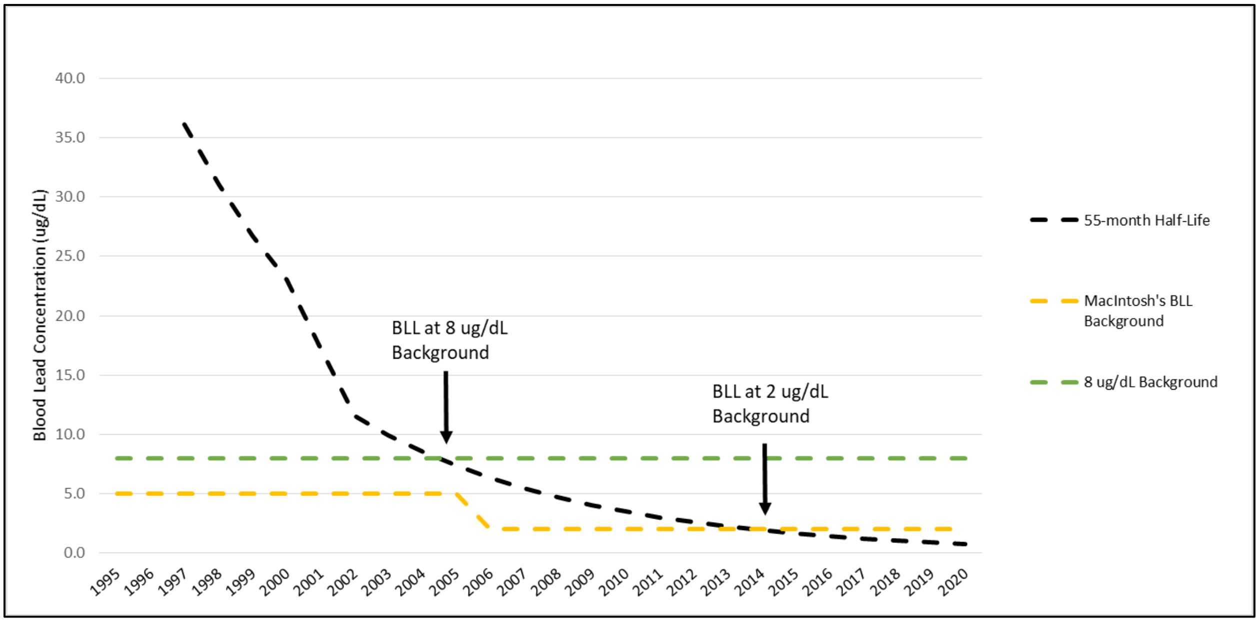


Figure 7. Dr. MacIntosh's hypothetical decay model

[43] Ryer-Powder (2019, p. 21) cites even higher background BLLs in various parts of Peru, including those reported for Callao, which is "*representative of an area with mineral storage area contaminated with lead*" with background BLL of "*9.6 µg/dL (standard deviation of 6.2)*."

- As displayed in Figure 8, Dr. MacIntosh's decay formula used in his blue line model indicates that after cessation of DRP operations in 2009, the BLLs of La Oroya Antigua children would have fallen below the 8 µg/dL background level by 2013, and below his own assumed 2 µg/dL background level by 2015. Dr. MacIntosh does not provide any support for his unsubstantiated and counterintuitive claim.

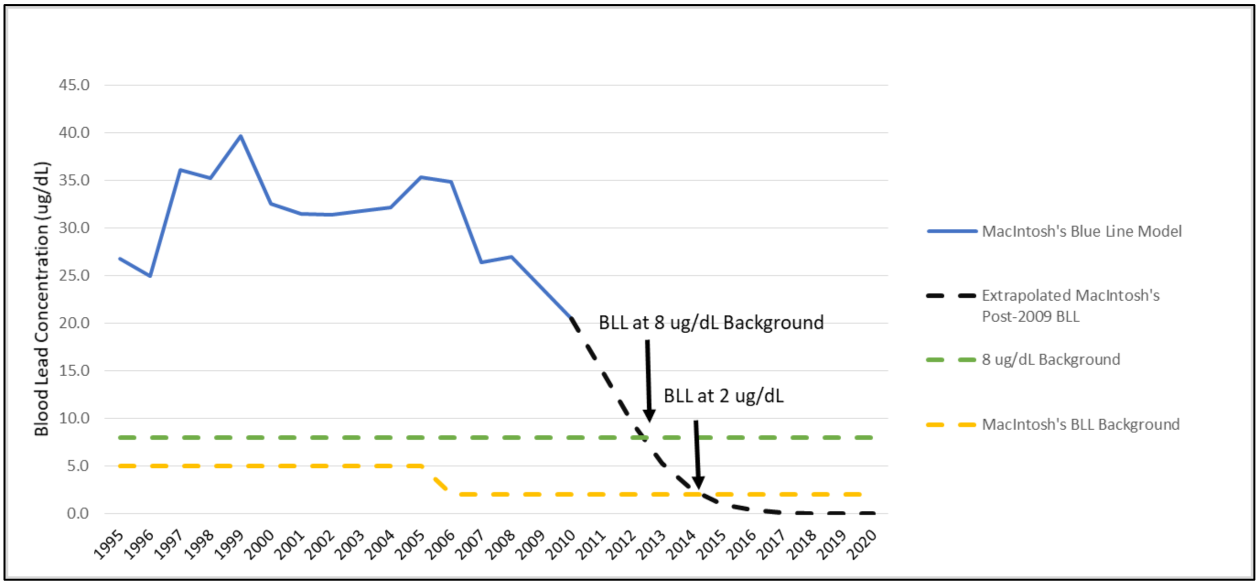


Figure 8. Dr. MacIntosh's post-DRP BLL decay model

57 After my review of Dr. MacIntosh's allocation models, I conclude that his predictive models are statistically flawed, speculative, and yield counterintuitive results. Such models are inappropriate foundations for any allocation exercise.

4.5 Opinion 5: Mr. Sullivan's air model is an unreliable model that according to EPA's cited guidance should be disregarded.

58 Mr. Sullivan generates a dispersion air model to predict the average air concentrations for a number parameters at each of the Plaintiffs' receptor points. He also generalizes his model results by producing isopleth maps of air concentrations for each parameter for the entire surrounding region. However, Mr. Sullivan fails to conduct any proper evaluations of the reliability of his model. This is contrary to EPA guidance recommendations that he himself cites in his report.

4.5.1 Evaluation of Mr. Sullivan's model

59 Mr. Sullivan cites an EPA guidance document on air quality models[44] to indicate that air models are not intended to be accurate when paired observed and modeled values are constrained in time and space. He then references an EPA air model application document, which makes a general statement that "*For model evaluation studies, a factor of two agreement between modeled and observed values is generally considered to be acceptable.*"[45] Instead of conducting a quantitative

[44] Mr. Sullivan's reference 143.
[45] Mr. Sullivan's reference 152, p. 8.

evaluation, Mr. Sullivan makes the conclusory statement that results of his "*Scenario 2.5H were generally within a factor of +/- two of the average measured concentrations but with most of the modeled results lower than comparable measured concentrations (typically about half of the measured concentrations).*"[46] The term "*factor*" cited in the EPA document refers to the relative magnitudes of paired modeled and observed results. Under such a definition, acceptable model results are those whose ratios of predicted over observed values vary between 2 and 0.5. I assumed that Mr. Sullivan's reference to "*a factor of +/- two*" is also consistent with this definition.

60 I conducted an evaluation of Mr. Sullivan's air model by using his own reported paired measured and modeled results listed in his Tables E-13 through E-15. Contrary to Mr. Sullivan's claims, as listed in Table 4, the majority of his model results for various locations and years do not meet a "*factor of two*" agreement with their corresponding observed values, and thus, cannot be considered as acceptable under EPA guidance recommendations cited by Mr. Sullivan. For such models, EPA (1992 p.7) suggests "*consideration may be given to excluding that model from further evaluation due to its **limited credibility** for refined regulatory analysis* [emphasis added]." Mr. Hoffnagle provides a more thorough review of the inner working of Mr. Sullivan's unreliable model.

Table 4: Quantitative Evaluation of Mr. Sullivan's Models
(Highlighted cells fail the factor-of- two agreement)

ANALYTE	MODEL TIME BASIS	YEAR	SITE	MODELED	MEASURED	FACTOR
Arsenic	Annual Average	2001	CASA	0.05	0.43	0.11
Arsenic	Annual Average	2001	CUSH	0.32	1.13	0.29
Arsenic	Annual Average	2001	HUAN	3.11	7.19	0.43
Arsenic	Annual Average	2001	INCA	1.36	1.84	0.74
Arsenic	Annual Average	2001	SIND	9.62	3.38	2.85
Arsenic	Annual Average	2006	CASA	0.05	0.94	0.06
Arsenic	Annual Average	2006	CUSH	0.65	1.43	0.46
Arsenic	Annual Average	2006	HUAN	3.64	5.53	0.66
Arsenic	Annual Average	2006	INCA	2.34	2.05	1.14
Arsenic	Annual Average	2006	SIND	10.43	3.48	2.99
Arsenic	Annual Average	2007	CASA	0.04	0.17	0.23
Arsenic	Annual Average	2007	HUAN	2.30	4.01	0.57
Arsenic	Annual Average	2007	HUAR	0.05	0.39	0.13
Arsenic	Annual Average	2007	HUAY	0.05	0.18	0.29
Arsenic	Annual Average	2007	INCA	0.78	0.83	0.94
Arsenic	Annual Average	2007	MARC	0.14	0.42	0.34
Arsenic	Annual Average	2007	SIND	3.65	1.01	3.62
Arsenic	Annual Average	2008	CASA	0.06	0.11	0.54
Arsenic	Annual Average	2008	HUAN	2.01	4.43	0.45
Arsenic	Annual Average	2008	HUAR	0.05	0.52	0.10
Arsenic	Annual Average	2008	HUAY	0.07	0.28	0.24
Arsenic	Annual Average	2008	INCA	0.94	0.90	1.04
Arsenic	Annual Average	2008	MARC	0.17	0.40	0.42
Arsenic	Annual Average	2008	SIND	4.92	1.42	3.46
Lead	Max 3-month running average	2001	CASA	0.10	0.55	0.19
Lead	Max 3-month running average	2001	CUSH	0.50	1.45	0.34
Lead	Max 3-month running average	2001	HUAN	5.78	12.21	0.47
Lead	Max 3-month running average	2001	INCA	1.40	2.61	0.54
Lead	Max 3-month running average	2001	SIND	10.66	4.07	2.62
Lead	Max 3-month running average	2006	CASA	0.10	1.04	0.10
Lead	Max 3-month running average	2006	CUSH	0.69	2.11	0.33

[46] Sullivan 2019, p. 85.

Table 4: Quantitative Evaluation of Mr. Sullivan's Models
(Highlighted cells fail the factor-of- two agreement)

ANALYTE	MODEL TIME BASIS	YEAR	SITE	MODELED	MEASURED	FACTOR
Lead	Max 3-month running average	2006	HUAN	5.57	10.62	0.52
Lead	Max 3-month running average	2006	INCA	1.89	2.97	0.63
Lead	Max 3-month running average	2006	SIND	14.73	4.89	3.01
Lead	Max 3-month running average	2007	CASA	0.08	0.42	0.18
Lead	Max 3-month running average	2007	HUAN	1.92	6.47	0.30
Lead	Max 3-month running average	2007	HUAR	0.08	0.77	0.10
Lead	Max 3-month running average	2007	HUAY	0.10	0.45	0.23
Lead	Max 3-month running average	2007	INCA	1.02	1.27	0.80
Lead	Max 3-month running average	2007	MARC	0.21	1.03	0.21
Lead	Max 3-month running average	2007	SIND	5.11	2.09	2.45
Lead	Max 3-month running average	2008	CASA	0.10	0.26	0.40
Lead	Max 3-month running average	2008	HUAN	3.17	9.51	0.33
Lead	Max 3-month running average	2008	HUAR	0.10	1.00	0.10
Lead	Max 3-month running average	2008	HUAY	0.13	0.51	0.26
Lead	Max 3-month running average	2008	INCA	1.45	1.14	1.28
Lead	Max 3-month running average	2008	MARC	0.30	0.73	0.41
Lead	Max 3-month running average	2008	SIND	6.80	1.61	4.23
SO_2	99th Percentile Daily Max 1-hour	2006	CASA	881	1,380	0.64
SO_2	99th Percentile Daily Max 1-hour	2006	CUSH	4,307	5,541	0.78
SO_2	99th Percentile Daily Max 1-hour	2006	HUAN	10,265	23,182	0.44
SO_2	99th Percentile Daily Max 1-hour	2006	INCA	9,600	14,231	0.67
SO_2	99th Percentile Daily Max 1-hour	2006	SIND	15,186	16,450	0.92
SO_2	99th Percentile Daily Max 1-hour	2007	CASA	803	1,577	0.51
SO_2	99th Percentile Daily Max 1-hour	2007	CUSH	1,872	3,153	0.59
SO_2	99th Percentile Daily Max 1-hour	2007	HUAN	8,810	27,246	0.32
SO_2	99th Percentile Daily Max 1-hour	2007	HUAR	1,107	5,513	0.20
SO_2	99th Percentile Daily Max 1-hour	2007	HUAY	1,238	1,926	0.64
SO_2	99th Percentile Daily Max 1-hour	2007	INCA	9,295	11,552	0.80
SO_2	99th Percentile Daily Max 1-hour	2007	MARC	2,651	5,184	0.51
SO_2	99th Percentile Daily Max 1-hour	2007	SIND	18,167	16,539	1.10
SO_2	99th Percentile Daily Max 1-hour	2008	CASA	1,215	3,938	0.31
SO_2	99th Percentile Daily Max 1-hour	2008	HUAN	8,557	23,951	0.36
SO_2	99th Percentile Daily Max 1-hour	2008	HUAR	985	5,053	0.19
SO_2	99th Percentile Daily Max 1-hour	2008	HUAY	1,986	2,853	0.70
SO_2	99th Percentile Daily Max 1-hour	2008	INCA	7,416	14,743	0.50
SO_2	99th Percentile Daily Max 1-hour	2008	MARC	2,726	4,428	0.62
SO_2	99th Percentile Daily Max 1-hour	2008	SIND	17,818	17,540	1.02

61 Instead of a quantitative evaluation of his air models in accordance with EPA guidance recommendations, Mr. Sullivan presents a series of linear regressions of his modeled versus measured results (Sullivan 2019, Tables E-13 through E-15). In each of these regressions, Mr. Sullivan uses a different time basis to pair his modeled results to the measured values. In Table E-14, he compares annual averages, while in Table E-15, he compares the 99th percentiles of daily maximums. In Table E-13, maximum three-month averages are compared, which in some cases correspond to 9-month lags between the occurrence of the paired measured and modeled values. Although regression results are not intended to demonstrate the accuracy of a model, Mr. Sullivan seems to be presenting these regression results in support of the reliability of his air models. My review of these reported regressions confirms that Mr. Sullivan's model results are systematically biased.

62 Mr. Sullivan's listed measured and modeled results in his Tables E-13 through E-15 exclude data from the Sindicato Station. In fact, Mr. Sullivan devotes a large portion of Section 6.4 of his report

to portray measured data at the Sindicato Station as "non-representative." However, as described by others, I understand that Mr. Sullivan's arguments for the exclusion of the Sindicato Station are without basis. In addition, Dr. MacIntosh relies heavily on the Sindicato measurements in his own models.[47]

63 The Sindicato Station is the nearest air monitoring station to the CMLO facility. Mr. Sullivan's arguments seem to be motivated by the fact that his model results consistently <u>overestimate</u> air concentrations when compared to those measured at this station. As listed in Table 5, Mr. Sullivan's own reported model results consistently indicate large overestimations of Sindicato Station measurements. Mr. Sullivan ignores the fact that by rejecting the Sindicato Station data, he is further reducing the reliability of his model results within the most investigated area of La Oroya.

Table 5. Mr. Sullivan's model predictions at Sindicato Station representing La Oroya Antigua
(Highlighted cells represent over-estimated values)

Analyte	Description	Model	Year	Modeled	Measured	Over-Estimation (%)
Lead	Maximum 3-month Average	Base	2001	23.75	4.07	484%
Lead	Maximum 3-month Average	Base	2006	23.39	4.89	378%
Lead	Maximum 3-month Average	Base	2007	7.16	2.09	243%
Lead	Maximum 3-month Average	Base	2008	12.96	1.61	705%
Lead	Annual Average	Base	2001	16.5	2.67	518%
Lead	Annual Average	Base	2006	15.74	3.62	335%
Lead	Annual Average	Base	2007	3.78	1.19	218%
Lead	Annual Average	Base	2008	8.3	1.36	510%
Arsenic	Annual Average	Base	2001	14.28	3.38	322%
Arsenic	Annual Average	Base	2006	14.23	3.48	309%
Arsenic	Annual Average	Base	2007	4.57	1.01	352%
Arsenic	Annual Average	Base	2008	7.54	1.42	431%
SO2	99th Percentile Daily Maximum 1-Hour	Base	2006	59,392	16,450	261%
SO2	99th Percentile Daily Maximum 1-Hour	Base	2007	1,226	1,926	-36%
SO2	99th Percentile Daily Maximum 1-Hour	Base	2008	1,987	2,853	-30%
Lead	Maximum 3-month Average	2.5H	2001	10.66	4.07	162%
Lead	Maximum 3-month Average	2.5H	2006	14.73	4.89	201%
Lead	Maximum 3-month Average	2.5H	2007	5.11	2.09	144%
Lead	Maximum 3-month Average	2.5H	2008	6.8	1.61	322%
Lead	Annual Average	2.5H	2001	8.11	2.67	204%
Lead	Annual Average	2.5H	2006	9.93	3.62	174%
Lead	Annual Average	2.5H	2007	3.07	1.19	158%
Lead	Annual Average	2.5H	2008	5.33	1.36	292%
Arsenic	Annual Average	2.5H	2001	9.62	3.38	185%
Arsenic	Annual Average	2.5H	2006	10.43	3.48	200%
Arsenic	Annual Average	2.5H	2007	3.65	1.01	261%
Arsenic	Annual Average	2.5H	2008	4.92	1.42	246%
SO2	99th Percentile Daily Maximum 1-Hour	2.5H	2006	15,186	16,450	-8%
SO2	99th Percentile Daily Maximum 1-Hour	2.5H	2007	18,167	16,539	10%
SO2	99th Percentile Daily Maximum 1-Hour	2.5H	2008	17,818	17,540	2%
Lead	Maximum 3-month Average	2.0H	2001	18.05	4.07	343%
Lead	Maximum 3-month Average	2.0H	2006	18.09	4.89	270%
Lead	Maximum 3-month Average	2.0H	2007	7.78	2.09	272%
Lead	Maximum 3-month Average	2.0H	2008	9.34	1.61	480%
Lead	Annual Average	2.0H	2001	12.83	2.67	381%
Lead	Annual Average	2.0H	2006	13.29	3.62	267%

[47] MacIntosh (2019, Figure 9.6)

Table 5. Mr. Sullivan's model predictions at Sindicato Station representing La Oroya Antigua
(Highlighted cells represent over-estimated values)

Analyte	Description	Model	Year	Modeled	Measured	Over-Estimation (%)
Lead	Annual Average	2.0H	2007	4.73	1.19	297%
Lead	Annual Average	2.0H	2008	7.32	1.36	438%
Arsenic	Annual Average	2.0H	2001	11.39	3.38	237%
Arsenic	Annual Average	2.0H	2006	12.06	3.48	247%
Arsenic	Annual Average	2.0H	2007	4.73	1.01	368%
Arsenic	Annual Average	2.0H	2008	6.22	1.42	338%
SO2	99th Percentile Daily Maximum 1-Hour	2.0H	2006	29,204	16,450	78%
SO2	99th Percentile Daily Maximum 1-Hour	2.0H	2007	25,576	16,539	55%
SO2	99th Percentile Daily Maximum 1-Hour	2.0H	2008	24,930	17,540	42%

64 Rather than addressing the above over-estimation issues, Mr. Sullivan presents unsubstantiated arguments to reject the data collected at Sindicato Station. He ignores the fact that other Plaintiffs' experts, including Dr. MacIntosh, rely on the measured values at Sindicato Station. Mr. Sullivan's rejection of Sindicato Station data raises serious doubts about the technical reliability of claims made by Plaintiffs' experts.

4.5.2 Mr. Sullivan's unreliable isopleth maps

65 Mr. Sullivan seems to be using the output of his unreliable dispersion model to create isopleth maps,[48] which he refers to as the "predicted" maps.[49] These maps cover various parameters across areas surrounding the CMLO. As discussed earlier, Mr. Sullivan's model results lack adequate accuracy at locations where monitoring data are available. The accuracy of his model results are expected to be even lower at locations lacking such monitoring data. Mr. Sullivan ignores these facts and presents his isopleth contour maps without any mention or evaluation of their accuracy.

66 In the absence of any measure of accuracy of the predicted values, Mr. Sullivan's isopleth maps cannot be considered as statistically reliable. This is especially problematic for La Oroya Antigua, where Mr. Sullivan's model consistently produces biased high estimates of air concentrations, as listed in Table 5.

4.5.3 Use of Mr. Sullivan's unreliable results by other Plaintiffs' experts

67 Some of the Plaintiffs' experts have relied on Mr. Sullivan's unreliable isopleth model results. For example, Dr. Ryer-Powder uses Mr. Sullivan's model results for annual average arsenic values[50] and the 99th percentile of 1-hour daily maximum SO_2 values[51] at residences and schools of the selected Plaintiffs in 2001, 2006, 2007 and 2008. Nearly 80% of these residences and 35% percent of the schools are situated in La Oroya Antigua. Dr. Ryer-Powder ignores the fact that Mr. Sullivan's model consistently overestimates air concentrations in this area as listed in Table 5.

[48] Sullivan 2019, Isopleth maps presented in Section 6.10.
[49] Mr. Sullivan's "predicted" values in his Tables E-13 through E-15 are adjusted modeled values in accordance to regression equations between modeled and measured results.
[50] Ryer-Powder 2019, Table 14, p. 33
[51] Ryer-Powder 2019, Table 20, p. 45

Reliance on such inflated results casts serious doubts on the technical reliability of Dr. Ryer-Powder's opinions.

68 Dr. MacIntosh uses Mr. Sullivan's unreliable modeling results to support his own opinions by stating that: "… *the modeling analysis done by David Sullivan shows that air quality impacts of the facility are largest along the sides of the valleys*."[52] Later on, Dr. MacIntosh states: "[Mr. Sullivan's] *modeling establishes a meteorological link between operations of CMLO and air lead concentrations in the communities*."[53] Dr. MacIntosh's statements are quite puzzling when considering that Mr. Sullivan's modeling results are predicated on the <u>rejection</u> of the Sindicato Station data - the very station that constitutes the vast majority of input air lead concentration data in Dr. MacIntosh's predictive models. In fact, Dr. MacIntosh's predictive model, partially presented in his Figure 9.4, is generated by correlating 5,009 pairs of measured BLLs and their nearest measured air concentration data. Of these, 4,215 pairs or 84% of the pairs are based on the Sindicato Station measured values.

69 Dr. MacIntosh justifies his use of Mr. Sullivan's modeling results by stating that "*the modeled air lead concentrations are strongly correlated with the lead concentrations measured in La Oroya*."[54] Dr. MacIntosh's endorsement is especially problematic when considering that the alleged "strong correlations" are only attained by ignoring Sindicato Station data – the very dataset that forms the foundation of Dr. MacIntosh's predictive models.

70 Dr. MacIntosh's statement also ignores the fact that the alleged "strong correlations" between Mr. Sullivan's modeled and measured results are not necessarily indicative of an accurate and reliable model. The "strong correlations" that Dr. MacIntosh is referring to seem to be those reported in Mr. Sullivan's Tables E-13 through E-15. As discussed earlier, these regressions simply indicate that Mr. Sullivan's models are not accurate and suffer from systematic bias. Unfortunately, MacIntosh (2019) does not provide any further discussions about Mr. Sullivan's modeling or mapping results.

4.6 Opinion 6: Dr. Cheremisinoff's regressions conducted as part of his evaluation of DRP's efficiency improvements reveal a general misunderstanding of basic statistical concepts.

71 Dr. Cheremisinoff's report focuses on quality of care, best practices, emissions capture/reduction technology, and fugitive emissions estimation of the CMLO during DRP's tenure. Dr. Cheremisinoff attributes emissions reductions to decreased production rather than to any control interventions implemented by DRP.

4.6.1 Dr. Cheremisinoff's misinterpretation of linear regression results

72 Dr. Cheremisinoff presents Exhibits 139 and 140 to support his claim that DRP's mitigation actions had no impact on improving air quality in the early years of its operations (1997 – 2003).

[52] MacIntosh 2019, p. 11
[53] MacIntosh 2019, p. 17
[54] MacIntosh 2019, p.17

For this purpose, Dr. Cheremisinoff arbitrarily divides DRP's operations into two subjective periods of pre- and post-2003 without any explanation or rationale. He then states: "*Exhibit 139 shows PM* [particulate matter] *trend charts for period 1* [pre-2003] *showing no impacts from Defendants' actions on air quality.* ***There is no statistically significant correlation****. In comparison, the PM trend charts for period 2* [post-2003] *(Exhibit 140) shows a statistically significant impact from actions taken by Defendants to reduce the emissions resulting in improved air quality* [emphasis added]*.*"

73 Dr. Cheremisinoff's Exhibits 139 and 140 display time regressions of his own calculated monthly "Plantwide" total suspended particulates (TSP) discharges during two arbitrary periods. I understand these calculated TSP values are highly questionable (Libicki 2019). Even if these values are considered acceptable, the above-cited statement by Dr. Cheremisinoff about "*no statistically significant correlations*" indicates that he has a general misunderstanding of basic statistical principles such as "*significance.*" In fact, both of his regressions in his Exhibits 139 and 140 display statistically significant emissions reductions, as listed in Table 6. As explained below, Dr. Cheremisinoff seems to be confusing the magnitude of "R-squared" with "statistical significance" of a linear regression.

Table 6. Linear regression results of Dr. Cheremisinoff's computed monthly Plantwide TSP emissions

	1997-2003	2003-2007
Coefficient (Monthly TSP Reduction Rate, MT/month)	-2.8665	-12.0999
R-squared	0.2585	0.7757
p-value	0.000007	<0.00000000000000022

74 Dr. Cheremisinoff misinterprets the R-squared value of 0.2585 for his first arbitrary period (November 1997 – August 2003) as "*no statistically significant correlations*" compared to the R-squared of 0.772 for his second arbitrary period (September 2003 – December 2008). However, as shown in Table 6, both of these time periods exhibit p-values less than 0.05, and thus are statistically significant decreasing trends. These results indicate that the observed decrease in emissions during Dr. Cheremisinoff's arbitrary first period has a p-value of 0.000007, *i.e.*, a 0.0007% chance of occurring randomly. During his arbitrary second period the p-value drops even further to a value less than 0.00000000000000022. These p-values indicate that the observed decreasing patterns during both periods are statistically significant.

75 Contrary to Dr. MacIntosh's predictive models, in this case, Dr. Cheremisinoff is solely interested in assessing the presence of any discernable linear relationship between his TSP values and time, *i.e.*, he is not interested in predicting "Plantwide" TSP discharges at months when such values are missing. Under such a condition, p-values less than 0.05 can be used to conclude that both periods display statistically-significant decreasing emission trends. If he wanted to use these models for predictive purposes, then the listed R-squared values could be used to conclude that the linear regression in his second period is capable of producing more reliable predictions than those predicted by his first period regression.

4.7 Opinion 7: Dr. Cheremisinoff's manipulations of air monitoring data are overtly biased and unreliable.

76 Dr. Cheremisinoff claims that the "Defendants' reporting practices of their monitoring data are deceptive and misleading."[55] He indicates that the SO_2 monitoring data has "numerous hourly data entries in the workbook for which there are zero (0) and No (---) values. These are included in the Defendants' calculated averages, which is unreasonable" to include in computed monthly averages.[56] However, Dr. Cheremisinoff fails to explain or prove that a reported 0 value from a monitoring station is indicative of a missing value. My review indicates that such missing values have been clearly marked with "---.", and 0 values should properly be understood to mean measured results of 0.

77 Dr. Cheremisinoff uses the SO_2 air concentration data from the Sindicato Station for the month of June 2005 as an example to assert: *"Defendants* [DRP] *report a monthly mean SO_2 concentration of 390 µg/m3 based on their method of averaging. By excluding the 0- and No-value data entries, the "true" monthly average concentration based on the actual measurements is calculated to be 520.3 µg/m3. That is a 33% difference (i.e., the reported monthly average concentration is 33% lower than the true monthly average). Defendants reporting practices of their monitoring data are deceptive and misleading."*[57]

78 Ironically, DRP did not include the non-measured SO_2 values when computing the monthly average, as Dr. Cheremisinoff accuses. I reviewed the referenced SO_2 dataset and determined that of the 720 possible date/time values for the month, 707 had valid numerical values and only 13 were missing data. I computed the average of the non-missing measured values and derived a mean of 390 $\mu g/m^3$, the same value originally provided by DRP. Dr. Cheremisinoff's approach to computing the monthly average SO_2 concentrations results in a biased mean which, for June 2005, is 33% overestimated.

79 To compound this error, Dr. Cheremisinoff elects to substitute the reported 0 values with their preceding non-zero values. Table 7 provides a summary of the number of SO_2 measurements that Dr. Cheremisinoff substituted for each year. By substituting actual 0 measured values with a higher value, Dr. Cheremisinoff has manipulated the monitoring data in an overtly biased manner. In this case, the reported 0 values are analogous to the non-detect results. Substituting such results with the much higher preceding values is inconsistent with EPA guidance-recommended options on treating non-detect values.[58] Unfortunately, Dr. Cheremisinoff utilizes his incorrect and biased SO_2 dataset for all his subsequent analyses, which render his conclusions unreliable.

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[55] Cheremisinoff 2019, p.101.
[56] Cheremisinoff 2019, p.100.
[57] Cheremisinoff 2019, p.101.
[58] https://www.epa.gov/risk/regional-guidance-handling-chemical-concentration-data-near-detection-limit-risk-assessments

Table 7. Number of 0 and missing SO_2 value substituted by Dr. Cheremisinoff

Year	Count of Substituted Values
2001	165
2002	107
2003	82
2004	34
2005	430
2006	18
2007	66
2008	819
2009	112

80 Dr. Cheremisinoff's Exhibit 17 implies that SO_2 measurements at Sindicato Station prior to 5/24/2006 were right-censored, *i.e.*, the instrument measurements were limited to approximately 6,000 µg/m^3. Cheremisinoff (2019, p. 100) refers to these potentially censored data as biased low. However, in subsequent analyses, he relies on mixtures of these potentially-censored and uncensored SO_2 data to build his various claims. Some of Dr. Cheremisinoff's exhibits based on mixings of potentially censored and uncensored data are listed in Table 8. In constructing these exhibits, Dr. Cheremisinoff fails to use the appropriate statistical procedures that are specifically designed to treat right-censored data (Qin and Shen 2010). These procedures include readily available R packages to calculate statistics of right-censored data.[59]

Table 8. Examples of Dr. Cheremisinoff's exhibits using data that he considers as potentially censored data

Exhibit Number	Reliance on Potentially Censored Data
18	Presented hourly values for June 2005
20	Mixture of daily averages of potentially censored and uncensored data
21	Mixture of monthly averages of potentially censored and uncensored data
22	Mixture of 12-month moving monthly averages of potentially censored and uncensored data
24	Mixture of monthly averages of potentially censored and uncensored data

4.8 Summary and Conclusions

81 Upon a thorough review of statistical models, calculations, and conclusions presented in reports submitted by Dr. David L. MacIntosh, Mr. David A. Sullivan, and Dr. Nicolas P. Cheremisinoff related to the CMLO case, I reached the following conclusions.

82 My review of MacIntosh (2019) indicated a number of fundamental deficiencies in his statistical modeling and computations that render his presented results devoid of any technical credibility. My findings are summarized as a number of opinions:

[59] https://cran.r-project.org/web/packages/survival/survival.pdf

- Opinion 1: Dr. MacIntosh's predictive models are based on a fundamentally unscientific procedure.
- Opinion 2: Dr. MacIntosh's predictive models are not statistically reliable.
- Opinion 3: Dr. MacIntosh presents misleading results in support of his unreliable predictive models.
- Opinion 4: Dr. MacIntosh's allocation computations are based on unreliable and speculative models.

83 My review of Sullivan (2019) indicated that the presented air model fails the EPA's base screening level which renders the model devoid of any technical reliability. My findings are summarized as the following opinion:

- Opinion 5: Mr. Sullivan's air model is an unreliable model that according to EPA's cited guidance should be disregarded.

84 My review of the statistical components of Cheremisinoff (2019) which included regression analyses as part of his evaluation of DRP's efficiency improvements, led me to following opinions:

- Opinion 6: Dr. Cheremisinoff's regressions conducted as part of his evaluation of DRP's efficiency improvements reveal a general misunderstanding of basic statistical concepts.
- Opinion 7: Dr. Cheremisinoff's manipulations of air monitoring data are overtly biased and unreliable.

5 REFERENCES

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Sullivan, David. (2019). Air quality & meteorological analysis of the Doe Run Peru Smelter and Refinery Operations in the vicinity of La Oroya, Peru.

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6 COMPENSATION

Fees for my services including review of documentation and production of reports are billed by NewFields Companies, LLC, at an hourly compensation rate of $395. My compensation is in no way connected to or dependent on the conclusions that I have reached in this case.

7 OTHER WITNESS INFORMATION

In the last four years, I have provided testimony in the following cases:

- Expert for Defendants in "NL Industries, Inc. v. ACF Industries, *et al.*," Docket No. 10-cv-00089 (EAW)(HBS), United States District Court, Western District of New York, 2015 (Deposition).
- Expert for Plaintiff in "City of Los Angeles v. BAE Systems San Diego Ship Repair, Inc." Case No. 13-CV-8810 CBM(AGRx), United States District Court, Central District of California, 2016. (Deposition)
- Expert for Defendants in Case No.: 2:17-cv-01624-ES-SCM "Duarte et al. v. United States Metals Refining company et al." in the United States District Court for the District of New Jersey, 2019 (Depositions).

8 CURRICULUM VITAE

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EDUCATIONAL BACKGROUND

Ph.D.	1983	Harvard University	Environmental Sciences
S.M.	1980	Harvard University	Engineering
B.A.	1978	University of California, Berkeley	Economics
B.S.	1978	University of California, Berkeley	Civil Engineering

PROFESSIONAL EXPERIENCE

President	NewFields Companies, LLC	1995 - Present
Editorial Board Member	*Environmental Forensics* Association for Environmental Health and Sciences	2003 - Present
Adjunct Professor	School of Civil and Environmental Engineering Georgia Institute of Technology	1996 - 2004
Associate Professor	School of Civil and Environmental Engineering Georgia Institute of Technology	1990 - 1996
Senior Consultant	Dames & Moore Atlanta, GA	1990 - 1995
Chairman	National Ground Water Hydrology Committee, Hydraulics Division, American Society of Civil Engineers	1991 - 1992
Expert Member	ASTM/EPA/USGS/DOD Geostatistics Standardization Committee	1991 - 1998
Associate Editor	*Water Resources Research* American Geophysical Union	1989 - 1994
Assistant Professor	School of Civil Engineering Georgia Institute of Technology	1983 - 1990
Chairman	Task Committee on Geostatistical Techniques in Geohydrology, American Society of Civil Engineers	1987 - 1989
National Science Foundation Visiting Scientist	*Centre de Géostatistique*, *Ecole Nationale Supérieure des Mines de Paris*, France	1987 - 1988

PROFESSIONAL REGISTRATION

Licensed Professional Engineer — Georgia (Registration Number 19369)

CURRENT FIELD OF INTEREST

Geostatistics
Environmental Statistics
Geostatistical and Stochastic Hydrology
Decision Analysis
Groundwater and Surface Hydrology

HONORS AND AWARDS

Tau Beta Pi (National Engineering Honor Society)	1977
Chi Epsilon (Civil Engineering Honor Society)	1978
Phi Beta Kappa (National Honor Society for Students in Social Sciences)	1978
Watson Award, Division of Applied Sciences, Harvard University	1979-82
Sigma Chi (Scientific Research Society)	1987
1990 Who's Who (Rising Young Americans)	1990
ASCE Task Committee Excellence Award, Hydraulics Division (S. Rouhani, Chairman of ASCE Task Committee on Geostatistical Techniques in Geohydrology)	1991
Dictionary of International Biography - 22nd Edition	1992
Two Thousand Notable American Men, First Edition	1992
Who's Who in America	1995-Present

REPRESENTATIVE PROJECT EXPERIENCE

Government Sector Sample Projects

NOAA Assessment of Deepwater Horizon MC252 Oil Impacts – Principal investigator for development of statistical sampling designs and conducting statistical analyses for various shoreline technical working groups as part of NRDA evaluation.

United Nations Compensation Commission Expert Assessment – Extensive sediment and soil data provided associated with the environmental damages from post-1991 Kuwait conflict were statistically and geostatistically analyzed. These analyses were conducted as part of the UNCC technical review of submitted claims.

US EPA Project on Multivariate Geostatistical Trend Detection and Network Design for Acid Deposition Data– Principal investigator for development of a multivariate geostatistical technique for trend detection in acid deposition data and spatial evaluation of current national network, known as NAPD/NTN.

US EPA Project on Statistical Source Contamination Identification, Coleman-Evans Superfund Site, Whitehouse, FL – On behalf of EPA, extensive historical soil data were analyzed in order to determine the extent of ambient versus site-related dioxins.

US EPA Project on Statistical Source Contamination Identification, ACW Superfund Site, Pensacola, FL – On behalf of EPA, extensive historical soil data were analyzed in order to determine the extent of ambient versus site-related dioxins.

US EPA Guidance for Soil Cleanup Strategies – Principal author on geostatistical procedures for optimal soil cleanup delineation.

US Navy CURT (Clean Up Review Team) – Technical lead on strategic review of US Navy environmental restoration projects worldwide. In this role Dr. Rouhani assisted US Navy to review more than 750 projects and identify more than $100 million in cost-avoidance.

US Navy Mole Pier, San Diego Naval Station, CA – Project director for the data evaluation and analysis of the anticipated $40 million dollar clean-up project.

US Navy Allen Harbor Landfill, North Kingstown, RI – Project director for updating superfund remedy selection. The original cap remedy cost was estimated at $14 million.

US Navy, Cecil Field, Naval Air Station Jacksonville, FL – Project director for the geostatistical analysis of lead soil data at a former firing range. This project was later selected by the US EPA as a case study for an upcoming guidance document on optimal soil remedy selection at CERCLA sites.

US Navy, Mountain Creek Lake, NWIRP Dallas, TX – Principal investigator for the sediment background analysis. This innovative study led to an expedited approval of sediment delineation, while avoiding a potentially expensive and time-consuming ecological risk assessment.

US Navy RITS Lectures and CECOS Classes – Principal lecturer at US Navy Remediation Innovative Technology Seminar (RITS), as well as a regular lecturer at CECOS courses on Environmental Background Analysis, Navy Environmental Restoration Program, and Environmental Sampling Design and Data Quality Assessment.

US Department of Energy Project on Application of Geostatistical Methods to Savannah River Site Environmental and Geotechnical Investigation, SC – Principal investigator for development and application of advanced procedures for evaluation of the adequacy of groundwater quality data at a waste site, as well as development of geostatistical estimation/simulation procedure in support of seismic modeling of the site.

South Florida Water Management District, US Sugar Land Acquisition, FL – Developed and negotiated the approval of statistical procedures for due diligent sampling and analysis process, conducted the statistical analysis of due diligent soil samples, developed confirmatory sampling and analysis process, and participated in technical discussions and negotiations.

St. Johns River Water Management District Minimum Flow Determination, FL – Developed an innovative combined hydrodynamic and statistical approach to establish minimum flow levels for Blue Spring based on protection of manatees winter refuge criteria.

St. Johns River Water Management District Geostatistical Peer Review, FL – Lead technical reviewer for numerous projects at SJRWMD, including optimization of groundwater monitoring networks, mapping of potentiometric surfaces, groundwater flow modeling, assessment of seagrass monitoring protocols, Lake Apopka soil data analysis, and time series analysis of groundwater and lake monitoring data.

South Florida Water Management District Lower West Coast Potentiometric Mapping, FL – Technical lead on statistical and geostatistical analysis of available seasonal, multi-layer groundwater elevation data for Lower West Coast potentiometric Mapping.

<u>Private Sector Sample Projects</u>

Anniston Lead Site, Anniston, AL – Lead negotiation, cleanup, and sampling efforts at Anniston Lead Site, Alabama. These efforts included statistical and geostatistical analyses of soil lead and PCB data in order to verify the extents of zones of investigations.

Alabama Wood Treaters Site, Mobile, AL – Principal investigator concerning a legal dispute on cost recovery. This project involved analysis of an extensive list of historical documents and aerial photographs.

RFI Investigation, Middlesex, NJ – Principal investigator for soil arsenic background data analysis. This project involved compilation and analysis of large historical datasets for determining arsenic background concentrations.

Geostatistical Source Impact Delineation, Mission Valley, San Diego, CA – Extensive BTEX, MTBE groundwater database was geostatistically analyzed in order to define the extent of site-related plumes.

Groundwater statistical optimization, Athens, GA – Assessment of soil and groundwater at manufacturing facility in Athens, Georgia. Geostatistics was used to (1) characterize the groundwater contamination in a three-dimensional framework, and (2) identify areas which figure either data gaps, or potentially elevated contaminations. Geostatistically produced kriged and quantile maps were used to characterize the site contamination, as well as identify location for subsequent sampling activities.

Statistical Risk Evaluation, Detroit, MI – Principal investigator for risk assessment study of a major development site. Geostatistics were used to estimate surface soil block contamination, evaluate the adequacy of the existing surficial measurements, and design an information-efficient deep soil sampling plan.

Soil Characterization Planning and Optimization, Charleston, SC – An innovative phased geostatistical sampling plan was developed to characterize soil and groundwater contamination at a RCRA industrial site in South Carolina.

Groundwater Transport Modeling for Remedial Evaluation, Atlanta, GA – Determined the effectiveness of a proposed list of groundwater remedial alternatives at a CERCLA site through the use of U.S. Geological Survey groundwater flow/transport model, MOC-2D. The results of the model provided a realistic assessment of long-term potential efficiency of the various pump-and-treat alternatives.

Risk Evaluation of Contaminated Sites in Michigan – Existing soil data from an abandoned industrial site in Michigan were geostatistically analyzed to perform two tasks: (1) to characterize the site contamination in a multi-layer framework, and (2) identify areas which figure either data gaps, or potentially elevated contaminations.

Spatial Statistical Assessment, Baton Rouge, LA – Performed an extensive soil and groundwater analysis at a CERCLA site in Baton Rouge, Louisiana. Site was geostatistically analyzed in order to perform four major tasks: (1) to characterize three-dimensional soil contamination mapping, (2) to calculate block-area groundwater contamination levels, (3) to produce sampling plans for subsequent measurements, and (4) to provide the most accurate information on the spatial distribution of Analytes of the groundwater flow/transport model of the site.

Data Analysis at a Former Refinery, Peñuellas, Puerto Rico – Principal investigator for the compilation and analysis of available soil and groundwater, as part of a RCRA Facility Investigation.

Statistical Assessment of Migration Potential, Memphis, TN – Principal investigator for the geostatistical analysis of existing data on the thickness of a critical near-surface aquitard to determine zones of potential leakage to the lower aquifer.

GEORGIA TECH REPRESENTATIVE STATISTICAL RESEARCH EXPERIENCE

Title:	Optimal Sampling of Stochastic Processes
Sponsor:	National Science Foundation
Duration:	(6/1/85 to 10/30/87)
Subject:	In this project, Dr. Rouhani developed optimal sampling and monitoring techniques for ground water quantity and quality investigations, based on advanced geostatistical procedures. It was shown that using such techniques can yield economically efficient sampling plans.

Title:	Optimal Schemes for Ground Water Quality Monitoring in the Shallow Aquifer, Dougherty Plain, Southwestern Georgia
Sponsor:	U.S. Geological Survey
Duration:	(4/1/86 to 3/31/87)
Subject:	In this project, Dr. Rouhani developed a flexible geostatistical procedure for planning a ground water quality monitoring network in Dougherty Plain, Georgia. The proposed network acts as a warning system for the protection of the Floridian Aquifer system which is a major source of water in south Georgia and Florida.

Title:	Advanced Geostatistical Studies at the Centre de Geostatistique, Ecole des Mines de Paris.
Sponsor:	National Science Foundation
Duration:	(9/1/87 - 2/18/89).
Subject:	Through this project Dr. Rouhani developed new techniques for statistical analysis of space-time data, including air pollution and ground water contamination data. The budget of this project was the highest amount awarded by the NSF's "U.S. - Industrialized Countries Program for the Exchange of Scientists and Engineers" in 1987.

Title: Geostatistical Evaluation of Flow Analytes
Sponsor: U.S. Geological Survey
Duration: (4/1/90 - 3/31/91)
Subject: Dr. Rouhani developed techniques for efficient estimation of ground water flow Analytes based on available hydrogeological field data.

Title: Multivariate Geostatistical Trend Detection and Network Design for Acid Deposition Data
Sponsor: U.S. Environmental Protection Agency
Duration: (3/1/1991 -9/30/1991)
Subject: Dr. Rouhani developed a multivariate geostatistical technique for trend detection in acid deposition data and spatial evaluation of current national network, known as NAPD/NTN.

Title: Multilayer Geostatistical Ground Water Flow and Transport Modeling
Sponsor: HazLab, Inc.
Duration: (6/20/92 -12/30/92)
Subject: Dr. Rouhani developed a combined deterministic/geostatistical groundwater flow/transport model.

Title: Velocity/Lithology Model Database, Statistical Models of Soil Columns Velocity, and Maps of Model Layers
Sponsor: Westinghouse Savannah River Company / U.S. DOE
Duration: (1/1/1993-6/30/1993)
Subject: Dr. Rouhani developed a relational database and conducted extensive geostatistical analyses of seismic data.

Title: Application of Geostatistical Methods to SRS Groundwater Monitoring and Environmental Risk
Sponsor: Westinghouse Savannah River Company / U.S. DOE
Duration: (7/1/1993-10/15/1993)
Subject: Dr. Rouhani developed procedures for evaluation of the adequacy of groundwater quality data at a waste site.

Title: H-Area/ITP Geostatistical Assessment of In-situ and Engineering Properties
Sponsor: Westinghouse Savannah River Company / U.S. DOE
Duration: (1/1/1994-6/30/1995)
Subject: Dr. Rouhani will develop geostatistical estimation/simulation procedure in support of seismic modeling of the site.

PUBLICATIONS

Published Books and Parts of Books

1. Rouhani, S., and T.J. Hall, "Geostatistical Schemes for Groundwater Quality Management in Southwest Georgia," in Pollution, Risk Assessment, and Remediation in Groundwater Systems, pp. 197-223, R.M. Khanbilvardi and J. Fillos, Eds., Scientific Publications Co., Washington, DC, 1987.
2. Rouhani, S., and R. Kangari, "Landfill Site Selection," in Expert Systems: Applications to Urban Planning, Ch. 10, T.J. Kim *et al.*, Eds., Springer-Verlag, 1989.
3. Lennon, G.P., and S. Rouhani, Eds., Ground Water, Proceedings of the ASCE International Symposium on Ground Water, ASCE, 1991.
4. Rouhani, S., R. Srivastava, A. Debarats, M. Cromer, and I. Johnson, Eds., "Geostatistics for Environmental and Geotechnical Applications," STP 12 83, ASTM, 1996.
5. Wellington, B., and Rouhani S., "Environmental Statistics," in Sustainable Land Development and Restoration: Decision Consequence Analysis, pp. 311-323, K. Brown *et al.*, Eds., Butterworth-Heinemann, New York, NY, 2010.

6. Uhler, A.D., Stout, S.A., Emsbo-Mattingly, S.D., and Rouhani S., "Chemical Fingerprinting: Streamlining Site Assessment during the Sustainable Redevelopment Process," in Sustainable Land Development and Restoration: Decision Consequence Analysis, pp. 311-323, K. Brown *et al.*, Eds., Butterworth-Heinemann, New York, NY, 2010.

Standards and Guidance Documents (Main Author/Contributing Author)

1. American Society of Testing and Materials (ASTM), Standard Guide for Reporting Geostatistical Site Investigations, D5549-94, 1994.
2. American Society of Testing and Materials (ASTM), Standard Guide for Analysis of Spatial Variation in Geostatistical Site Investigations, D5922-96, 1996.
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5. Department of Navy (DON), Guidance for Environmental Background Analysis, Volume I: Soil, NFESC User's Guide, UG-2049-ENV, April 2002.
6. Department of Navy (DON), Guidance for Environmental Background Analysis, Volume II: Sediment, NFESC User's Guide, UG-2054-ENV, April, 2003.
7. Department of Navy (DON), Guidance for Environmental Background Analysis, Volume III: Groundwater, NFESC User's Guide, UG-2059-ENV, April, 2004.
8. Department of Navy (DON), Guidance for Environmental Background Analysis, Volume IV: Vapor Intrusion Pathway, User's Guide, UG-2091-ENV, Interim Final, April 2011.
9. United States Environmental Protection Agency (US EPA), *Guidance for Soil Cleanup Strategies*, Draft, 2003.

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1. Rouhani, S., "Variance Reduction Analysis", *Water Resources Research*, Vol. 21, No. 6, pp. 837-846, June, 1985.
2. Rouhani, S., "Comparative Study of Ground Water Mapping Techniques", *Journal of Ground Water*, Vol. 24, No. 2, pp. 207-216, March-April 1986.
3. Rouhani, S., and Fiering, M.B., "Resilience of a Statistical Sampling Scheme," *Journal of Hydrology*, Vol. 89, No. 1, pp. 1-11, December, 1986.
4. Rouhani, S., and Kangari, R., "Landfill Site Selection: A Microcomputer Expert System," *International Journal of Microcomputers in Civil Engineering*, Vol. 2, No. 1, pp. 29-35, March, 1987.
5. Rouhani, S., and Hall, T.J., "Geostatistical Schemes for Groundwater Sampling," *Journal of Hydrology*, Vol. 103, 85-102, 1988.
6. Rouhani, S., and Cargile, K.A., "A Geostatistical Tool for Drought Management," *Journal of Hydrology*, Vol. 106, 257-266, 1989.
7. ASCE Task Committee on Geostatistical Techniques in Geohydrology (S. Rouhani, Chairman and Principal Author), "Review of Geostatistics in Geohydrology, 1. Basic Concepts," *ASCE Journal of Hydraulic Engineering*, 116(5), 612-632, 1990.
8. ASCE Task Committee on Geostatistical Techniques in Geohydrology (S. Rouhani, Chairman and Principal Author), "Review of Geostatistics in Geohydrology, 2. Applications," *ASCE Journal of Hydraulic Engineering*, 116(5), 633-658, 1990.
9. Rouhani, S., and H. Wackernagel, "Multivariate Geostatistical Approach to Space-Time Data Analysis," *Water Resources Research*, 26(4), 585-591, 1990.
10. Rouhani, S. and D.E. Myers, "Problems in Space-Time Kriging of Geohydrological Data," *Mathematical Geology*, 22(5), 611-624, 1990.
11. Loaiciga, H.A., R.J. Charbeneau, L.G. Everett, G.E. Fogg, B.F. Hobbs, and S. Rouhani, "Review of Ground-Water Quality Monitoring Network Design," *ASCE Journal of Hydraulic Engineering*, 118(1), 11-37, 1992.
12. Rouhani, S., R. Ebrahimpour, I. Yaqub, and E. Gianella, "Multivariate Geostatistical Trend Detection and Network Evaluation of Space-Time Acid Deposition Data, 1. Methodology," *Atmospheric Environment*, 26A(14), 2603-2614, 1992.
13. Rouhani, S., R. Ebrahimpour, I. Yaqub, and E. Gianella, "Multivariate Geostatistical Trend Detection and Network Evaluation of Space-Time Acid Deposition Data, 2. Application to NADP/NTN Data," *Atmospheric Environment*, 26A(14), 2615-2626, 1992.

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15. Rouhani, S., Geostatistical Estimation: Kriging, in Rouhani *et al.*, Eds., "*Geostatistics for Environmental and Geotechnical Applications*," STP 12 83, ASTM, 1996.
16. Wild, M. R., and S. Rouhani, Effective Use of Field Screening Techniques in Environmental Investigations: A Multivariate Geostatistical Approach, in Rouhani *et al.*, Eds., "*Geostatistics for Environmental and Geotechnical Applications*," STP 12 83, ASTM, 1996.
17. Lin, Y. P., and S. Rouhani, "Geostatistical Analyses for Shear Wave Velocity," *J. of The Geological Society of China*, Vol. 40, No. 1, p 209-223, 1997.
18. Lin, Y.P., and S. Rouhani, "Multiple-Point Variance Analysis for Optimal Adjustment of A Monitoring Network," *Environmental Monitoring and Assessment*, 69(3), pp. 239-266, 2001.
19. Lin, Y. P., Y. C. Tan, and S. Rouhani, "Identifying Spatial Characteristics of Transmissivity Using Simulated Annealing and Kriging Methods," *Environmental Geology*, 41:200-208, 2001.
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21. Zengel, S., C. L. Montague, S. C. Pennings, S. P. Powers, M. Steinhoff, G. Fricano, C. Schlemme, M. Zhang, J. Oehrig, Z. Nixon, S. Rouhani, and J. Michel, "Impacts of the Deepwater Horizon Oil Spill on Salt Marsh Periwinkles (Littoraria irrorata)," *Environ. Sci. Technol.*, 50(2): 643-652, 2016.
22. Willis, J. M., M. Hester, S. Rouhani, M. Steinhoff, M. Baker, "Field Assessment of the Impacts of Deepwater Horizon Oiling on Coastal Marsh Vegetation of Mississippi and Alabama," *Environmental Toxicology and Chemistry*, (ETCJ-Nov-15-00911.R1), 2016.
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30. Gibbs, J. P., S. Rouhani, L. Shams. "Population status of freshwater turtles across a PCB contamination gradient." *Aquatic Biology*. 26: 57-68. 2017.
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32. Grabowski. J.H., S.P. Powers, H. Roman, and S. Rouhani. "Potential impacts of the 2010 Deepwater Horizon Oil Spill on subtidal oysters in the Gulf of Mexico." *Marine Ecology Progress Series*. 576:163-174, 2017.
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2. Chaudri, A., S. Rouhani and P.P. Rogers, "Hydrology of Induced Recharge in Indus Basin Pakistan," Department of City and Regional Planning, Harvard University, 1980.

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4. Rouhani, S. and T. J. Hall, "Optimal Schemes for Ground Water Quality Monitoring in the Shallow Aquifer, Dougherty Plain, Southwestern Georgia," Technical Completion Report, U.S. Dept. of Interior/USGS Project G-1219(05), ERC 05-87, Environmental Resources Center, Georgia Institute of Technology, Atlanta, Georgia, 49 p., 1987.
5. Rouhani, S., "Optimal Sampling of Stochastic Processes," Final Technical Research Report, National Science Foundation, Grant No. ECE-8503897, School of Civil Engineering, Georgia Institute of Technology, Atlanta, Georgia, p. 170,1987.
6. Rouhani, S., "*L'Analyse de Donnees Geohydrologiques*," De Geostatisticis, No. 3, pp. 5-6, August, 1988.
7. Rouhani, S., "Advanced Geostatistical Studies at the Centre de Geostatistique, Ecole des Mines de Paris," Final Technical Research Report, National Science Foundation, Grant No. INT-8702264, School of Civil Engineering, Georgia Institute of Technology, Atlanta, GA, 129 p., May 1989.
8. Rouhani, S., "Geostatistics: Theory, Practice, and Personal Computer Applications," Education Extension, Georgia Institute of Technology, September, 1989.
9. Rouhani, S., R. Ebrahimpour, I. Yaqub, and E. Gianella, "Multivariate Geostatistical Trend Detection and Network Evaluation of Space-Time Acid Deposition Data," Final Technical Report, AREAL, U.S. Environmental Protection Agency, Contract 68-D0-0095, RTP, NC, 320 p., October, 1991.
10. Rouhani, S., M. J. Maughon, and B. J. Weiss, "Geostatistical Mapping of Ground Water Contaminants," Technical Report, HazLab, Inc., Contract E-20-X18, School of Civil Engineering, Georgia Institute of Technology, Atlanta, January 1993.

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1. Rouhani, S., "Optimal Groundwater Data Collection, Waterlogging and Salinity Considerations," *Proceedings of the International Seminar on Water Resources Management*, Lahore, Pakistan, No. 3, pp. 167-182, October 1983.
2. Rouhani, S., "A Scheme for Water Resources Monitoring in Rural Areas," *Proceedings of the Vth World Congress on Water Resources*, IWRA, Vol. 2, pp. 701-710, June, 1985.
3. Kangari, R. and Rouhani, S., "Expert Systems in Reservoir Management and Planning," in *World Water Issues in Evolution, Water Forum '86*, M. Karamouz et al., Eds., Vol. 1, pp. 186-194, American Society of Civil Engineers, New York, 1986.
4. Rouhani, S., and R. Kangari, "Expert Systems in Water Resources," *Water for the Future: Hydrology in Perspective*, J. C. Rodda and N.C. Matalas, Eds., pp. 457-462, International Association of Hydrological Sciences, Publication No. 164, 1987.
5. Rouhani, S., and T.J. Hall, "Space-Time Kriging of Groundwater Data," in *Geostatistics*, M. Armstrong, Editor, Vol. 2, pp. 639-650, Kluwer Academic Publishers, Dordrecht, Holland, 1989.
6. Kangari, R., and Rouhani, S., "Knowledge-Based Systems in Water Resources Management," *Proceedings of the International Conference on Water and Wastewater*, pp. 588-593, Academic Periodical Press, Beijing, China, 1989.
7. Rouhani, S., "Geostatistics in Water Resources," *Proceedings of the 1989 Georgia Water Resources Conference*, K. J. Hatcher, Ed., pp. 169-171, Institute of Natural Resources, University of Georgia, Athens, Georgia, 1989.
8. Rouhani, S., and M. E. Dillon, "Geostatistical Risk Mapping for Regional Water Resources Studies," *Use of Computers in Water Management*, Vol. 1, pp. 216-228, V/O "Syuzvodproekt", Moscow, USSR, 1989. (Also in Russian: Vol. 2, pp. 234-249.)

PROFESSIONAL ACTIVITIES

1. American Geophysical Union:
   Member, 1981-Present.
   Associate Editor, *Water Resources Research*, 1989-1994.
2. American Society of Civil Engineering:
   Associate Member, 1983-1987.
   Member, 1987.
   Chairman, National Ground Water Hydrology Committee (Standing Committee), Hydraulics Division, Oct. 1991-1992.

Chairman, ASCE Task Committee on Geostatistical Techniques in Geohydrology, Ground Water Hydrology Technical Committee, American Society of Civil Engineers, Hydraulics Division, Oct. 1987-Sept. 1989.

Contact Member, ASCE Task Committee on Groundwater Monitoring Network Design, Probabilistic Approaches to Hydraulics and Hydrology Committee, Hydraulic Division, Oct. 1988- Sept. 1990.

Secretary, ASCE Water Resources Committee, American Society of Civil Engineers, Georgia Section, 1988.

Special Session Organizer, Special Session on "Development and Applications of Geostatistics in Geohydrology," 1989 ASCE National Conference on Hydraulic Engineering, New Orleans, August 14-18, 1989.

Special Session Organizer and Chairman, Special Session on Geostatistics in Geohydrology, 1990 ASCE Water Resources Conference, Fort Worth, April, 1990.

Symposium Organizer, International Symposium on Ground Water, 1991 ASCE National Conference on Hydraulic Engineering, Nashville, July, 1991.

3. International Water Resources Association: Member, 1985.
4. American Water Resources Association: Member, 1986.
5. North American Council on Geostatistics, 1987.
6. International Geostatistical Association: Member, 1989.
7. Association for Environmental Health and Sciences (AEHS):

   Member, 2003.

   Member of Editorial Board, *Environmental Forensics*, 2003-Present.

Rouhani's Expert Report (11/26/2019)
Errata Sheet

- Page 2, Paragraph 3, Line 3 should read "Sullivan, and Dr. Nicholas" instead of "Sullivan, Dr. Nicholas".
- Page 5, Footnote 7, Line 1 should read "MacIntosh (2019, p. 29)" instead of "MacIntosh (2019, p. 28)".
- Page 7, Paragraph 24, Line 2 should read "He cites four studies" instead of "He cites three studies".
- Page 7, Paragraph 24, Line 4 should read "Richmond-Bryant *et al.* (2013, 2014)" instead of "Richmond-Bryant *et al.* (2014)."
- Page 7, Paragraph 24, Line 6 should read "The third and fourth cited studies, Richmond-Bryant *et al.* (2013, 2014)" instead of "The third cited study, Richmond-Bryant et al. (2013)".
- Page 7, Paragraph 24, Line 8 should read "the above four studies" instead of "the above three studies".
- Page 7, Footnote 18 should read "EPA 2013, p. 3-119" instead of "EPA 2013, p. 3-118".
- Page 17, Footnote 37 should read "EPA (2013, p. 3-119)" instead of "EPA (2013, p. 3-118)".
- Page 18, Footnote 40, Line 2, the quotation should read *"...although the programs community hygiene continued..."* instead of *"...although the programs continued...."*
- Page 27, Paragraph 74, Line 3 should read "0.776" instead of "0.772"
- Page 28, Paragraph 76, Line 7 should read "---" instead of "---.".
- Page 28, Paragraph 79, Line 1 should read "the reported 0 and missing values" instead of "the reported 0 values".